

TERRESTRIAL MICROWAVE INTERACTIVE ADAPTIVE TRANSPONDER,
HORN-PARABOLIC ANTENNA,
AND RADOME FOR SUCH TRANSPONDER

Field of the Invention

5 The present invention relates:

Firstly, to such preferably low power terrestrial microwave interactive adaptive transponders, which –

are designed for radio and TV programs wireless transmission (as a rule, in digital format) and, simultaneously, for information services (in particular, Internet) providing
10 to numerous customers, and

are capable to operate under intensive atmospheric precipitations such as monsoon rains, lasting snowfalls, or dust and sand storms;

Secondly, to the design of horn-parabolic antennas for directional sector (i.e. fan-shaped) microwave radiation; and

15 *Thirdly*, to the design of radomes for said transponders' protection from atmospheric liquid and solid precipitations.

For the purpose of this description, the following terms as employed herein and in the appended claims refer to the following concepts:

20 "*Terrestrial transponder*" refers to transmitting-receiving (transceiving) radio system which –

is installed at an appropriate base in the surface air,

is equipped with connectors to an appropriate power supply source, and

comprises of transmitting and receiving circuits including each a set of data-isolated transmitting and receiving units for arbitrary digital and/or analogue data, all the above
25 controlled by an adaptive control system;

"*Microwave transponder*" refers to a transponder designed preferably for the SHF and the EHF bands operation;

"*Interactive transponder*" refers to a transponder designed for duplex mode data exchange with customers;

30 "*Adaptive transponder*" refers to a transponder designed for flexible adjustment of radio transmitting and receiving power level depending on the current humidity and/or dustiness values of the surface air.

Background Art

Multimedia services (i.e. providing of highly increasing number of corporate and
35 individual customers with reliable radio and TV broadcasting, effective duplex mobile wireless communication and high speed Internet access) have become one of the most significant segments of the world market.

Satisfaction of highly increasing solvent market demands for such services is really possible only using the microwave frequency band.

40 In fact, change of carrier frequency from UHF to SHF and EHF bands of

electromagnetic waves (hereinafter referred as EMW) enables to gain substantially throughput of radio-telephone channels and radio- and TV broadcasting and to transmit most of data in digital format which is less sensitive to electromagnetic interferences.

However, two basic disadvantages are accompanied to said advantages, namely:

5 (1) danger of the concentrated microwave electromagnetic radiation for people, that limits «physiologically» the power flux density of radio- and television transmitters and transponders, and

(2) intensive fading of radio signals according to increase of distance from the radio- and television transmitters or transponders, and, respectively, reduction of their service area.

10 Taking into consideration the factor (1), the International Consulting Committee for Radio Communications (ICCR) has defined in its Recommendations 406-6 (Düsseldorf, 1990, p.2) that –

the power at an input of transmitting antennas of any terrestrial radio system could not exceed +13 dBW and +10 dBW for the frequency bands 1–10 GHz and 10–15 GHz
15 respectively, and

maximum of equivalent isotropic radiated power for any such radio system could not exceed +55 dBW.

The factor (2), i.e. intensive fading of radio signals in atmosphere, is ridden on three main reasons.

20 The first reason of the power losses is EMW scattering in free space. These losses are proportional to the square of distance from the transmitter antenna to the receiver and inversely proportional to the square of radiated wavelength. So,

increase of distance from 1 to 50 km weakens a radio signal by 2500 times for any EMW in a radio frequency band, and

25 decrease of wavelength from 1m to 1 mm weakens a radio signal by 10^6 times (i.e. 60 dB regardless the distance).

The second reason of EMW power losses is absorption of electromagnetic energy by oxygen and atmospheric water. These losses have pronounced peaks for separate narrow frequency sub-bands. In particular, there are known two maxima of absorption:

30 15 dB/km at about 60 GHz frequency, and 2 dB/km at about 120 GHz frequency for the oxygen, and

0.15 dB/km at about 22 GHz frequency, and 25 dB/km at about 165 GHz frequency for the atmospheric water.

Oxygen concentration is practically constant in the surface air.

35 Therefore, the above mentioned losses caused by EMW scattering in free space and EMW energy absorption by oxygen can be easy taken into account at the time of designing of radio and TV broadcasting stations, transponders and customer transceivers.

However, air humidity may vary within wide range.

Moreover, under sick fogs, rains and/or snowfalls the air may be so saturated by water

drops and/or snowflakes that transmission of EMW in SHF and EHF bands become practically ineffective due to electromagnetic energy losses to heat atmospheric water.

This absorption is the third by number (but the main by importance for the damp tropical climate regions) reason of the energy losses and operational instability of any terrestrial transponders.

Ad notam, relationship between attenuation coefficient of vertical polarisation EMW (γ , dB/km) and rain intensity (R , mm/h) regarding carrier frequencies 12, 18, 28, and 38 GHz is given in the *Table 1* below:

Table 1

	Rain intensity, R , mm/h	Carrier frequency, GHz			
		12	18	28	38
EMW attenuation coefficient, γ , dB/km	5	0.11	0.3	0.75	1.3
	10	0.28	0.65	1.6	2.5
	50	2.2	3.8	7.8	12.0
	100	5.0	8.0	16.0	22.0

It's clear from the Table 1 that the attenuation coefficient grows greatly according to increase of the rain intensity (for each frequency) and according to increase of the frequency (for fixed rain intensity). So, at the EMW frequency 12 GHz and at distance 10 km from the radiation source the losses are 1.1 dB and 50 dB under 5 mm/h and 100-mm/h the rain intensity respectively. Analogously, at the frequency 28 GHz and the same distance and rain intensity the losses are 7.5 dB and 160 dB respectively.

Frequently the dustiness of the surface air makes also negative influence on terrestrial transponders' functioning owing to random scattering of microwave radiation.

It is known that traditional technical solutions of problems concerning increase of distance and reliability of wireless microwave radio communication under high humidity and/or dustiness either have little effectiveness or are impossible in principle.

For example, antenna lifting as high as possible over the day surface is the traditional way to increase coverage area of any radio and TV transmitters. Any natural uplands, masts, towers, high buildings and other suitable bases and, nowadays, geostationary broadcasting and telecommunication satellites, are used for this purpose.

However, these means can not reduce the negative influence of high humidity and dustiness on the EMW propagation in the surface air. Moreover, the mentioned above "physiological" factor restricts terrestrial radio and TV transmitters' power.

Therefore, in reality there are two ways for increase of reliability of wireless microwave radio communication in the surface air:

- (1) perfection of users' transceivers, i.e. Customer Premises Equipment (CPE), and
- (2) improvement of microwave terrestrial transponders together with their accessories.

One of the "fresh" attempts of improvement of CPE operated at various distances from a terrestrial transponder of satellite radio signals is known from US Patent Application No.20050020204 A1 dd. January 27, 2005. The proposed CPE is equipped with an antenna

comprising a passive unit, an active unit and a decoder.

The passive unit receives radio signals and transmits these signals to the active unit that comprises of at least one amplifier-converter. It converts the signals of initial frequency into signals of intermediate frequency (IF) and amplifies at least one of such signals. The
5 decoder analyses IF-signals continuously and sends commands to the active unit for adaptive gain control in order to maintain an acceptable level of IF-signals at the decoder input. It provides stable operation of the CPE in wide dynamic range of receiving radio signals under conditions of their fade or saturation.

Unfortunately, the described above CPE operates in radio receiving mode only and
10 thus is not suitable for duplex mode operation. Moreover, its dynamic range is insufficient for stable operation under conditions of intensive atmospheric precipitations.

Therefore, improvement of terrestrial transponders, their antennas and auxiliary devices is a preferable way in order to provide physiological safety and reliable data exchange when demand for multimedia information services and telecommunications
15 network development increase.

Unfortunately, transponders being practically used were not, in principle, designed with consideration to overcome action of atmospheric precipitations and dustiness on efficiency of transponder-CPE data exchange. Therefore, they operate, as a rule, at the threshold of physiological sensibility of people to the UHF, SHF and EHF radiation.

20 In fact, many of the known transponders are equipped usually with receiving antenna adjusted to the nearest radio- or TV transmitter or geostationary satellite, a power supply unit, an amplifier and an omnidirectional transmitting antenna.

The simplest example is the well-known MMDS (Multichannel Multipoint Distribution System) transponder. It was designed for simplex 24 analogue SECAM TV programs
25 broadcasting within 40-km radius service area radiating fixed 100 W per channel of amplitude-modulated signal within 2.5-2.686 GHz narrow bandwidth where EMW-energy losses under action of atmospheric precipitations are insignificant.

There are more perfect transponders such as:

LMDS (Local Multipoint Distribution Service) that was created originally for preferably
30 cellular TV frequency-modulated broadcasting in 27.5-29.5 GHz frequency band, and

MVDS (Multipoint Video Distribution System) that was created for 40.5-42.5 GHz analogue and/or digital multimedia services providing by duplex cellular communications using frequency-modulated signals.

The wide (2 GHz) operating frequency bandwidths of these systems is sufficient in
35 principle for creation of multimedia network providing simultaneously analogue and digital TV programs broadcasting, radiotelephony and high-speed Internet access.

It is clear, that real service areas of such transponders depend substantially on weather conditions. Therefore, reliable coverage of service area having radius up to 5 km for LMDS and up to 3.3 km for MVDS may be provided if each channel has radiating power not

less than 100 mW even for continental Europe weather conditions.

Designers of the microwave access system WiMax (Worldwide Interoperability for Microwave Access, IEEE 802.16e standard, December 2005) made an attempt to bypass said problems by refuse from radio- and TV broadcasting and providing "last mile" wireless
5 broadband Internet access only. In fact, WiMax was designed for Internet connecting via 802.11 standard public access points and is, in reality, "an extension" of cable and DSL lines up to 60 m in high-populated residential areas and up to 1.5–3.5 km in suburbs.

Evidently, EMW attenuation caused by atmospheric precipitations and dustiness would enhance as the required service area increases. Thus, increasing of the transmitters' power
10 and transmitting and receiving antennas' gain should compensate the losses.

UA Patent 51495 and WO 03/088523 (23.10.2003) disclose the MITRIS (Microwave Integrated TeleRadiolInformation System). In the contrast to WiMax, its transponder is equipped with 16 dB gain omnidirectional antenna with linear polarisation and is designed for 11.7–12.5GHz TV programs simplex transmission within 60 km radius with each channel 18
15 MHz bandwidth and 50 mW output power.

This system does not meet contemporary multimedia market demands and does not provide reliable data traffic under heavy atmospheric precipitations and dustiness.

More perfect Microwave Interactive Distributive Information System (MIDIS) is known from WO 2004/039076 (06.05.2004). It is equipped with transponder named "central station"
20 and nonempty set of CPEs (i.e. customers' transceivers).

The known transponder comprises of transmitting and receiving circuits, including:

- (1) an omnidirectional transmitting antenna,
- (2) at least one analogue TV broadcasting trunk, including:
 - an analogue video signal receiving unit,
 - 25 - a video signal modulator connected to said receiving unit output, and
 - an analogue channel transmitter connected to said modulator output, and, through a combiner, to said omnidirectional antenna input;
- (3) at least one digital TV broadcasting trunk, including:
 - a channel converter for the digital video signal receiving,
 - 30 - a digital video signal encoder connected to said converter output,
 - a digital video signal modulator connected to said encoder output, and
 - a digital video signal transmitter connected:
 - o to said modulator output through the first input,
 - o to said converter through the second input, and,
 - 35 o via the combiner and through the output, to the omnidirectional antenna input;
- (4) at least one data transmitting direct channel trunk, including:
 - a direct channel former,
 - a direct channel modulator connected to said former output, and
 - a direct channel transmitter connected to said modulator output and, through the

combiner, to the omnidirectional antenna input;

(5) a return channel main receiving station, including:

- receiving *horn antennas* which have sectoral radiation patterns and are meant to cover 360° service area,
- 5 - down converters connected to the antennas inputs,
- a divider having the number of outputs equal to the number of the antennas and connected to the converters outputs,
- demodulators connected to the divider output,
- at least one access server connected to the demodulators output, and
- 10 - a data service centre equipped with a router having nonempty set of outputs to be connected to external data sources and connected to an access server.

In practice, such data service centre is a local area network of information and communication servers with access to Ethernet interface through said router.

15 The transponder described above was designed to operate preferably in continental climate. Therefore, its *radome* against atmospheric precipitations may be a usual dome-shaped awning.

The described microwave terrestrial interactive transponder provides:

- conversion of data service centre Ethernet digital stream into DVB-S format and carrier frequency modulation by the transport DVB stream,
- 20 - connecting the customers to analogue and digital radio- and TV broadcast systems (with analogue-to-digital and digital-to-analogue signals related conversion),
- increasing of customers channels number by re-using of each return channel frequencies due to sectoral receiving, and
- 25 - TV broadcasting and data transmission and, if necessary, correction data transmission to developed CPE network.

30 This design allows increasing quality of services and reducing their costs as CPE network would be expanded. Used network layer protocols enables to insert arbitrary messages into the general data stream with simultaneous correction of CPE transceivers communication times. And, finally, layer services' application allows generating direct channels and «mixing» into general data stream the correcting data by the regular means.

35 However, it is impossible to adjust the transponder radiating power to current weather conditions using the omnidirectional transmitting antenna for all broadcasting and data trunks even by sectoral receiving circuit that is equipped with usual horn antennas formed as extensions of tapered waveguides.

Said MIDIS-transponder's disadvantage is not reasonable to eliminate by use of known receiving horn-parabolic antennas (HPA) with fan-shaped radiation pattern (SU 1622912; US 4,349,827; US 6,639,566 etc.). For example, HPA disclosed in SU 1622912 has basic elements made wholly from electroconductive material or at least coated inside by

it. In particular, this HPA comprises of:

- (a) a rectangular in cross-section horn, the input of which is connected to a feeding waveguide's end part, and
- (b) a parabolic reflector designed to be an extension of one of walls of said horn and located exactly opposite said horn's aperture.

Minimal back radiation is a typical feature of HPA enabling to minimise mutual interferences under their axis opposite location. But such interferences do not play an essential role when receiving weak CPE signals. Therefore, HPA implementation may be increased cost of existing transponders only.

Further, use of the omnidirectional transmitting antennas is forcing to use in known transponders such protective radomes, which are made almost in whole from expensive radio transparent materials and only sometimes (for making and mounting purpose) divided into a dome-shaped cover and a cylindrical casing (SU 1826564, UA 15023A, etc.).

Therefore, the known transponder in any embodiment is forced to operate at maximum power level even under fair weather. It pollutes environment with ballast electromagnetic radiation and causes interferences for other radio systems.

Summary of the Invention

The invention is based on the problem of creation of such terrestrial microwave interactive transponder, which would be capable to adapt in itself to current values of the EMW fading in surface air and, hence, to provide reliable functioning at the minimal radiated radio signals power respectively to the real EMW fading.

First of all, said problem is solved by change of structure of transmitting and receiving circuits of above-mentioned transponder. The improved *according to the invention* terrestrial microwave interactive adaptive transponder comprises of:

- (1) a transmitting circuit of direct channels of broadcasting and/or interactive data exchange with customers, which is –

divided into practically identical azimuthal sectors, and

equipped in each such sector with series of a microwave transmitter, an output waveguide and a transmitting horn-parabolic antenna providing fixed polarisation of radio signal;

- (2) a receiving circuit of return channels of interactive data exchange with customers, which is –

divided into such practically identical azimuthal sectors those are adjacent apex and in a horizontal projection practically coincide in pairs with the respective azimuthal sectors of the transmitting circuit, and

equipped in each such azimuthal sector with series of a receiving horn-parabolic antenna providing fixed polarisation of radio signal, an input waveguide and a microwave receiver,

at that in each pair of said azimuthal sectors of both said circuits

the parabolic reflectors of the transmitting and receiving horn-parabolic antennas have the common vertical symmetry plane, and

these antennas are adjusted on mutually orthogonal polarisations of radio signals;

(3) at least one router equipped with a means for connecting to the Ethernet-interface;

5 (4) at least one former of direct and return channels, which is connected to the informational outputs of said router and to the informational outputs of which are connected said microwave transmitters and receivers those operate on respective transmitting and receiving horn-parabolic antennas in each said azimuthal sector;

(5) at least one suitable power supply unit and separate circuits of feed and power
10 control of said microwave transmitters and separate feed circuits of said microwave receivers;

(6) a monitor of surface air and propagation of radio signals in each of azimuthal sectors of said transmitting and receiving circuits, and

(7) an adaptive power control unit of each of the microwave transmitters, which is
15 connected as a whole to the informational outputs of said monitor and to the control outputs of which the separate circuits of feed and power control of said transmitters are connected.

Even in this minimal configuration the proposed transponder is capable to tune automatically power of each of the microwave transmitters taking into account real humidity and/or dustiness of surface air in any separate azimuthal sector and in all these sectors
20 simultaneously. It allows exploiting the transponder on maximal permissible power only at the maximal fading EMW in the service area. In other cases the new transponder provides reliable data communication with customers on powers under permissible maximum.

Additional feature consists in that said receiving horn-parabolic antenna and its microwave receiver are located over respective said transmitting horn-parabolic antenna and
25 its microwave transmitter in each pair of said azimuthal sectors. It facilitates access from below to the equipment of transmitting circuit, which is more frequent, than receiving circuit, needs technical service and/or repair.

Other additional feature consists in that the microwave transmitters and the input waveguides of the all horn-parabolic antennas of the transmitting circuit and the output
30 waveguides and the microwave receivers of the all horn-parabolic antennas of the receiving circuit are located over the horns respective to them. It excludes practically cumulation of raindrops, snowflakes and dust in horns even in those cases, when the transponder would be operated without radome. Moreover, such arrangement of aforesaid elements is especially important in order to prevent accumulation of steam condensate on well-known
35 windows of the waveguides' vacuum seal assemblies of the microwave transmitters and the microwave receivers even at presence of the radome.

Further additional features consist in that –

each oh the transmitting and receiving circuits include $4N$ (where $N = 1, 2, 3$ etc.) said azimuthal sectors with angular value $90^\circ/N$ for the purpose of forming mutually additional

direct and return channels of broadcasting and interactive data exchange with customers,
said former of the direct and return channels is adjusted on the reiteration of working
frequencies in the direct channels through one pair of said azimuthal sector, and
the transmitting and receiving horn-parabolic antennas are adjusted to the same type
5 mutually orthogonal polarisations of radio signals through each two pairs of said azimuthal
sectors.

These additional improvements provide:

10 firstly, determination of those pair of said azimuthal sectors in which atmospheric
obstructions to the EMW propagation are most significant (that is important in the cases
when atmospheric precipitations or dust are distributed in the service area unevenly);

secondly, the 2N-multiple use of frequencies of the direct and return channels and,
accordingly, 2N-multiple increase of quantity of such channels is provided.

One more additional feature consists in that said adaptive power control unit in each
said microwave transmitter is supplemented with a gain controller in each said microwave
15 receiver. It allows applying the transponder according to the invention in combination with
standard customers' transceivers.

Last additional feature consists in that said former of the direct and return channels
has at least one additional input that is meant for connecting to an analogous TV signals
source. It extends the number of multimedia services.

20 Said problem is solved also by improvement of above-mentioned horn parabolic
antenna for said terrestrial microwave interactive adaptive transponder. This antenna
according to the invention has electroconductive in whole or at least covered inside by a
layer of electroconductive material parts such as:

(1) a rectangular feeding or receiving waveguide equipped with a suitable means for
25 fastening it to the respective microwave transmitter's or receiver's waveguide,

(2) a horn which is rigidly assembled with said rectangular waveguide and has:

two divergent walls assembled rigidly with two opposite walls of said rectangular
waveguide, and

30 two flat side walls being continuations of two other above-mentioned waveguide's
walls and bounded on one side by identical parabolic arcs;

(3) a parabolic reflector assembled rigidly with said flat side walls of the horn; and

(4) at least a two-stage trumpet being continuation of the horn and having an aperture
that exceeds the horn aperture in area extent.

Such horn parabolic antennas allow:

35 to form practically identical «fan» radiation patterns on two orthogonal (for example,
vertical and horizontal linear) polarisations,

to decrease substantially levels of cross-polarisation radiation and back radiation in the
cases when width of radiation patterns in azimuthal and elevation planes are differed
violently (in particular, tenfold or more times).

In this way such technical pre-conditions are created, which allow using said sectioned terrestrial microwave interactive adaptive transponders –

firstly, on identical frequencies and orthogonal polarisations through one said azimuthal sectors, and,

5 secondly, on identical frequencies and polarisations in diametrically opposite said azimuthal sectors.

Accordingly, it is really possible to divide circular multimedia transponder's service area on $4N$ (where $N = 1, 2, 3$. and etc.) azimuthal sectors and, hence, to except practically inter-sector interferences.

10 Additional feature consists in that said trumpet has two trapezoidal in profile stages at that the first stage's flare angle exceeds the flare angle of the second stage. It allows to optimise above-mentioned advantages by experimental selection of particular values of said flare angles.

15 Other additional feature consists in that said rectangular feeding waveguide or said receiving waveguide has square cross-section. It allows transmitting and receiving radio signals with arbitrary (including linear, circular and elliptic) polarisation, which may be provided by well-known polarizers and rotators.

And, finally, said problem is solved by improvement of the terrestrial microwave interactive adaptive transponder's radome from atmospheric precipitations. The radome
20 *according to the invention* comprises of:

(1) a dome-shaped roof, and

(2) a cylinder-like casing that is impenetrable for atmospheric precipitations and dust and rigidly assembled with the dome-shaped roof; the cylinder-like casing comprises of:

25 alternate protuberant ledges, the number of which corresponds to the number of the transponder's azimuthal sectors in the plan view and each of which has at least one radio transparent window,

smooth gutters which are located between said protuberant ledges and meant for draining of atmospheric precipitations, and

deflectors which are placed over each said radio transparent window.

30 Such radome is needed for protection of the transponder's transmitting and receiving antennas from atmospheric influences. This protection is especially important in regions having great average annual intensity of rains and/or snowfalls or dusty storms.

For example, the proposed radome provides effective draining of water streams in the periods of monsoon rains. Analogously, such radome prevents effectively sticking of snow
35 on the exterior radio transparent windows' surfaces.

It facilitates adaptive tuning of the transponder to current weather conditions and diminishes power losses at the transmission and receiving of microwave radio signals.

Additional feature consists in that the radome is equipped with impingement baffles which are fixed near the conjunction of said dome-shaped roof and said cylinder-like casing

and each of which envelopes partially with a gap the upper part of the corresponding protuberant ledge.

Further additional features consist in that said dome-shaped roof is formed as spheroid segment, or a pointed cone. These forms of said roof is the most preferable for protection of the transponders from rains or snow.

Last additional feature consists in that each said protuberant ledge has two spaced in height practically identical radio transparent windows. It facilitates separate montage and technical servicing of the transmitting and receiving horn-parabolic antennas.

To each person skilled in the art is clear that aforesaid additional features can be used in various combinations with the basic invention and that described below best embodiments of the invention in no way limit the scope of rights based on claims.

Brief Description of the Drawings

The invention will now be explained by detailed description of terrestrial microwave interactive adaptive transponder's construction and operation with references to the accompanying drawings, in which:

Fig.1 shows basic block diagram of the proposed transponder;

Fig.2 shows assembly of the transmitting and receiving circuits on an arbitrary base;

Fig.3 shows approximate block diagram of the proposed transponder's adaptive power control unit;

Fig.4 shows axonometric view of the proposed horn-parabolic antenna;

Fig.5 shows axonometric view of the proposed transponder's radome (and conventionally depicted heavy rain);

Fig.6 shows the horn-parabolic antenna position on the radome (partial plan view);

Fig.7 shows the proposed transponder's service area layout and an example of meteorological situation in such area (plan view);

Fig.8 shows graphic chart of dependence between power transmitted by customer's transceivers' and their distance from the transponder (against clear sky and heavy rain).

The best Embodiments of the Invention

Any terrestrial microwave interactive adaptive transponder according to the invention has the following non-denoted especially parts:

a transmitting circuit of the direct broadcasting and/or customers interactive data exchange channels, and

a receiving circuit of the return customers interactive data exchange channels.

Both these circuits are divided into practically the same asimuthal sectors, which are coincided in plan view but spaced in height. Correspondingly, Fig.1 shows:

a series of microwave transmitters 1 (additionally denoted as $T_1...T_{4N}$), output waveguides denoted only with arrows, and transmitting horn-parabolic antennas 2 (additionally denoted as $A_{T1}...A_{T4N}$) belonged to said transmitting circuit, and

a series of receiving horn-parabolic antennas 3 (additionally denoted as $A_{R1}...A_{R4N}$).

input waveguides denoted only with arrows, and microwave receivers 4 (additionally denoted as $R_1 \dots R_{4N}$) belonged to said receiving circuit.

The number of said transmitters 1, said horn-parabolic antennas 2 and 3, above-mentioned output and input waveguides and said receivers 4 are equal to the number of
5 aforesaid azimuthal sectors which are visible in plan view.

It is desirable if this number to be equal to $4N$ (where $N = 1, 2, 3$, etc.). Then the angular size of each said azimuthal sector (where the pair of mutually complemented transmitting 2 and receiving 3 horn-parabolic antennas is placed) will be equal to $90^\circ/N$.

Each said antenna 2 and each said antenna 3 is characterized by a specified radio
10 signal polarisation. At that –

parabolic reflectors shown and denoted below in each pair of adjacent apex transmitting $A_{T1} \dots A_{T4N}$ and receiving $A_{R1} \dots A_{R4N}$ horn-parabolic antennas have a common vertical symmetry plane, and

these antennas are adjusted to mutually orthogonal radio signals' polarisations.

15 Linear, circular and elliptic polarisation types and their various combinations are shown in Fig.1 at the left and at the right from symbolically denoted pairs of the respective transmitting and receiving antennas belonged to the direct and return channels. In particular, two such pairs of said mutually complementary antennas A_{T1} & A_{R1} and A_{T4N} & A_{R4N} and corresponding to them pairs the transmitters and the receivers located in different azimuthal
20 sectors may be clearly shown in said drawing.

It is desirable that in each said azimuthal sector the receiving horn-parabolic antenna 3 and its microwave receiver 4 are located above the transmitting horn-parabolic antenna 2 and its microwave transmitter 1 as it is clearly seen in Figs 1 and 2.

The proposed transponder must be equipped with a set of functional blocks for
25 effective operation of aforesaid receiving and transmitting circuits, namely (see Fig.1):

at least one router 5 having standard means for connection to the Ethernet interface and for provision of working with arbitrary digital data including digital video signals;

at least one former 6 of said direct and return channels, –

which is connected to the information inputs of router 5,

30 to the information outputs of which said microwave transmitters 1 and said microwave receivers 4 are connected those work together with the respective transmitting 2 and receiving 3 horn-parabolic antennas of said direct and return channels in each said azimuthal sector, and

to at least one input of which can be connected to the analogous television
35 broadcasting station (shown but not especially denoted);

at least one suitable power supply unit 7 and not shown here separate circuits of feed and power control of said microwave transmitters 1 and separate feed circuits of said microwave receivers 4;

a monitor 8 of surface air and radio signals propagation in each azimuthal sector of

said transmitting and receiving circuits, and

a multichannel adaptive power control unit 9 of each microwave transmitter 1, which is connected as a whole to the informational outputs of said monitor 8 and to the control outputs of which the above-mentioned separate circuits of feed and power control of said transmitters 1 are connected.

In a real transponder said units 8 and 9 are represented usually as an integral adaptive control system of said transmitting circuit (and, in some embodiments, of said receiving circuit) which, as a rule, is built in said former 6 of the direct and return channels. Microwave receivers 4 of the return channels may be used in such control system as sensors of atmospheric situation.

Fig. 2 shows such power control subsystem of a single microwave transmitter 1, which is a part of integral adaptive power control system. This subsystem has connected in series:

such return channel's demodulator 10, which is connected to the receiver's 4 output of the respective return channel meant for interactive data exchange with customers,

said adaptive power control unit 9, and

a modulator 11 connected to the input of the respective microwave transmitter 1.

Further Fig. 2 shows some features of arrangement of the proposed transponder on an intermediate support 12. This (as a rule, skeleton) support 12 is also used as a radome 13 bearer and may be fixed on a suitable basis (for example, on any housetop 14).

Finally, Fig.2 shows that the microwave transmitters 1 and the input waveguides of the all horn-parabolic antennas 2 (belonged to said transmitting circuit) as well as the output waveguides and the microwave receivers 4 of the all horn-parabolic antennas 3 (belonged to said receiving circuit) are located over the respective horns of all said antennas.

Fig.3 shows an approximate structure of one single channel of the multichannel adaptive power control unit 9 that is a part of the former 6 of said direct and return channels and is meant for regulation of the microwave transmitters' 1 power consumption. This unit 9 includes:

a bit errors analyser 15 connected to the outputs of the demodulators 10 of said return channels,

an unit 16 for decision-making on the output radio signals power adjustment according to real atmospheric situation; the unit 16 is connected to the analyser's 15 output,

an interface module 17 for transmission of commands concerning adjusting output power of microwave transmitter's 1 radio signals' in a single azimuthal sector, and

a controlled attenuator 18 to the input of which data sources (i.e. respective direct channels) are connected and to the output of which respective microwave transmitter 1 with the transmitting horn-parabolic antenna 2 are connected.

It is obvious to the persons skilled in the art that unit 9 (providing the microwave transmitters' 1 adaptive power control) may be supplemented with a not shown especially well-known gain control circuit for each microwave receiver 4. This circuit based usually on

multichannel controlled amplifier or, more desirable, on amplifiers that are built into said receivers 4 immediately.

It is advisable to equip the proposed transponder by horn-parabolic antennas (HPA) shown in Fig.4. Each HPA has electroconductive in whole or at least covered inside by a layer of electroconductive material parts such as:

a rectangular feeding or receiving waveguide 19 equipped with a suitable means for fastening it to the respective microwave transmitter's 1 or receiver's 4 waveguide (these means may be shaped as flanges 20),

a horn 21 which is rigidly assembled with said rectangular waveguide 19 and has:

two divergent walls 22 assembled rigidly with two opposite walls of said rectangular waveguide 19, and

two flat side walls 23 being continuations of two other above-mentioned waveguide's 19 walls and bounded on one side by identical parabolic arcs;

a parabolic reflector 24 that is assembled rigidly with said flat side walls 23 of the horn 21; and

at least a two-stage trumpet 25 being continuation of the horn 21 and having an aperture that exceeds the horn 21 aperture in area extent.

In practice it is sufficient if said trumpet 25 has two shown in Fig.4 trapezoidal in profile stages at that the first stage's flare angle exceeds the flare angle of the second stage.

It is most desirable if each waveguide 19 has square cross section.

The proposed antennas may be hingedly fastened on the transponder's base and equipped with well-known means of rotation and fixation (for example, turnbuckles). This provides adjustment of the transmitting 2 and receiving 3 antennas position in the elevation planes in each azimuthal sector of the service area that is especially important in the hilly and mountain terrain.

In the end of the proposed transponder description it is necessary to note that –

said former 6 of the direct and return channels is adjusted on the reiteration of working frequencies in the direct channels in each second azimuthal sector, and

the adjacent apex in pair the transmitting 2 and receiving 3 horn-parabolic antennas (A_{T1} & A_{R1}), (A_{T2} & A_{R2}) and so on till (A_{T4N} & A_{R4N}) are adjusted to the same type mutually orthogonal radio signals' polarisations in each third azimuthal sector.

It is advisable to equip the proposed transponder by an impenetrable for atmospheric precipitations and dust radome 13. This radome 13 has (see Fig.5):

a dome-shaped (for example, as a spheroid segment or a pointed cone) roof 26 made from water-proof (but not necessarily radio transparent) material, and

a cylinder-like casing that is rigidly assembled with said dome-shaped roof 26 and comprises of:

alternate protuberant ledges 27, the number of which corresponds to the number of the transponder's azimuthal sectors in the plan view and each of which has at least one

the transponder's azimuthal sectors in the plan view and each of which has at least one radio transparent window 28 (made, as a rule, from fibreglass plastics with polyester or epoxy binders, pure polystyrene, polyethylene, polypropylene, etc.),

5 smooth gutters 29 which are located between said protuberant ledges 27 and meant for draining of atmospheric precipitations, and

deflectors 30 which are placed over each said radio transparent window 28.

It is preferable if each said protuberant ledge 27 has two practically identical radio transparent windows 28 that are spaced in height. This is desirable for enabling easy access to the spaced in height the transmitting 2 and receiving 3 horn-parabolic antennas for their assembly, maintenance and substitution.

10 It is preferable too if impingement baffles 31 near the conjunction of said dome-shaped roof 26 and said cylinder-like casing are fixed. Each of said baffle 31 is usually rigidly connected with said roof 26 and envelops with a gap the upper part of the respective protuberant ledge 27.

15 Each such ledge 27 may be separately fastened on support 12 shown in Fig2. It is desirable for the purpose of easy assembly/disassembly of the mentioned radome 13 and access to the microwave transmitters 1 and/or microwave receivers 4 and to the transmitting 2 and receiving 3 horn-parabolic antennas located in separate azimuthal sectors during their service or repair.

20 Fig.6 shows the most clearly:

the horn-parabolic antenna 2 or 3 together with the respective microwave transmitter 1 or microwave receiver 4,

the radio transparent window 28 in one of the ledges 27 belonged to the radome's 13 cylinder-like casing, and

25 the smooth gutters 29 between the adjacent protuberant ledges 27.

To testing practicability and effectiveness of the invention one example of the proposed transponder equipped with said horn-parabolic antennas and said radome was made. Its service area was divided into eight equal azimuthal sectors of 45° with the general coverage of 360° (see Fig.7). Such transponder (together with customers' transceivers having parabolic receiving antennas) was meant to provide wireless customers' access:

30 first, to the digital video broadcasting transport streams generated with operators' equipment and complying to DVB-S (ETSI EN 300421, ISO/IEC 13818 - 1, 2, 3) standard;

second, to the digital IP networks and based on them information services through operators' IP-gateways connected to the transponder; and

35 third, to the transport streams of an analogue video broadcasting (by conversion of the input analogue video signals into MPEG-2 streams which are suitable for transmission in DVB standard).

The system comprises of said transponder and said customers' transceivers was designed to operate in line-of-sight conditions between the respective transponder's

the minimal and maximal radii of 500 m and 50 km respectively.

The one direct channel's bandwidth has occupied 28 MHz at the level of -3 dB and 36 MHz at the level of -20 dB.

5 The one return channel's bandwidth has occupied 2.2 MHz at the level of -3 dB and 3.5 MHz at the level of -30 dB.

The IP-packets throughput was adjusted no less than 30 Mbps in each direct channel and 2.4 Mbps in each return channel.

10 The transponder was designed for stable reception of digital and analogous television broadcasting and network access with no more than 2% losses of transmitted packets for the following distances R between the customers' transceivers and the transponder:

R = 8.5 km for the acceptable rain intensity of 65 mm per hour, and

R = 50 km for the clear sky.

Ad notam, the designed additional radio signal's attenuation in the rain with intensity 65 mm per hour at the distance of 8 km makes up 33 dB (see Fig. 8).

15 The time division multiplexing (TDM) was used in the direct channels for the customers' multiple access to the network. The maximal number of customers' transceivers serviced by one direct channel was given no less than 1500. The number of IP-addresses assigned to a single customer was given no more than 16 but total number of IP-addresses assigned per each direct channel was not exceeded the 1500.

20 The time-division multiple access (TDMA) was used in the return channels for the groups of customers. The maximal number of customer transceivers serviced by one return channel was no less than 128.

The proposed transponder in direct and return channels supports:

25 dynamic channel capacity distribution between single customer transceivers according to the guaranteed minimum and limited maximum strategies defined by operator;
priority traffic mode according to the rules specified by operator (the number of rules per one transceiver is up to 16).

It was provided in each azimuthal sector the concurrent functioning:

30 up to 12 direct channels (including 8 channels for digital video broadcasting with 64 programs and 4 channels for network access with throughput up to 120 Mbps), and
up to 24 return channels with total throughput of up to 57.6 Mbps.

The frequency band between 11.818 GHz and 12.7 GHz was selected for the direct channels.

35 This frequency band was used four times due to space and polarisation division of radio signals as shown in Table 2.

According to table 2 the separation of the direct channels' central frequencies makes 36 MHz while the central frequencies of radio signals within service area sectors being 90°C apart are shifted by 18 MHz.

Table 2

Sector's Number of the Service Area							
1	2	3	4	5	6	7	8
Operating Frequencies of the respective Sector, GHz							
11836 – 12268	12268 – 12700	11118 – 12250	12250 – 12682	11836 – 12268	12268 – 12700	11118 – 12250	12250 – 12682
Linear Polarisation Type (V – Vertical, H – horizontal)							
H	H	V	V	H	H	V	V

The frequency band between 10.95 and 10.286 GHz was given for return channels. This band was used two times due to space division of radio signals according to Table 3.

According to this Table 3 the separation of the return channels' central frequencies makes 3.5 MHz while the polarisation of the direct and return channels within each sector are orthogonal.

Table 3

Sector's Number of the Service Area							
	2	1	4	5	6	7	8
Operating Frequencies of the respective Sector, GHz							
10950.25 11034.25	11034.25 11118.25	11118.25 11202.25	11202.25 11286.25	10950.25 11034.25	11034.25 11118.25	11118.25 11202.25	11202.25 11286.25
Linear Polarisation Type (V – Vertical, H – horizontal)							
V	V	H	H	V	V	H	H

It was determined that in any sector:

a) total radio signals' power of microwave transmitter 1 concurrently transmitted on 12 direct channels should be:

- 10 no more than 120 mW (nominal level) during clear sky, and
 no more than 1.6 W (maximal level) during maximal rain intensity, while

b) total radio signals' power of microwave transceiver in each return channel should not exceed 35 mW.

15 Division of the transponder's service area into concentric sub-areas (see Fig.7) may achieve additional decrease of ballast radio-loading of air. Correspondingly, the maximal power of customers' microwave transmitters located in such sub-areas should be set at different levels according to their real distances from transponder (see Fig.8).

The described transponder and its above-mentioned components operate in the following way.

20 The direct and return channels former 6 (see Fig.1):

 receives initial data from Ethernet-interface through the router 5 (and if necessary from analogue video broadcasting system),

 generates together with said router 5 the direct channels necessary for broadcast in at least some azimuthal sectors and activates respective microwave transmitters 1 from the set (T₁... T_{4N}) together with respective horn-parabolic antennas 2 from the set (A_{T1}... A_{T4N}), and

25 receives through receiving horn-parabolic antennas 3 (A_{R1}... A_{R4N}) and respective microwave receivers 4 (R₁... R_{4N}) demands for service from customers located in single azimuthal sectors and directs each such demand to Ethernet-interface through said router 5,

which provides generation and maintenance of the transmitting and receiving channels pair for the time necessary to perform the service demand.

Specificity of the proposed transponder's operation (see Fig.2 and especially Fig.3) is the following.

5 The operating microwave receivers 4 ($R_1...R_{4N}$) allow determining dependence between radio signals propagation and the current atmospheric situation in each single sector of the transponder's service area.

Further obtained data pass through the demodulators 10 to the adaptive power control unit(s) 9 of the respective microwave transmitters 1. Thereto the analyser 15 recognises bit errors on the unit's 9 input. Then the unit 16 makes decisions regarding the necessary power and, through interface module 17 used as the unit's 9 output, transmits respective commands to the controlled attenuators 18. These attenuators 18 —

decrease the power radiated by such transmitters 1, which operate in sectors with clear sky, to aforesaid nominal value 120 mW,

15 determine (and maintain by modulators 11) the radiated power at levels sufficient to stable duplex communication with customers in all or some service area's sectors as weather gets worse.

The use of transmitting 2 and receiving 3 horn-parabolic antennas having trumpets 25 (see Fig.4) increase the communication's stability essentially:

20 first, due to rapid decrease of cross-polarisation, lateral and rear radiation's levels and
respective inter-sector interferences, and

second, due to orthogonality of any polarisation and, accordingly, due to additional increase (at least on 20-30 dB) of uncoupling between microwave transmitters 1 and receivers 4 in each azimuthal sector.

25 The proposed radome 13 (see once more Fig.5) provides effective draining of water streams effuse from the dome-shaped roof 26 and the deflectors 30 into the smooth gutters 29 even during heavy rainfalls. Impingement baffles 31 additionally prevent the formation of continuous water film on protuberant ledges 27 in general and, especially, on the outer side of the radio transparent windows 28.

30 *Industrial applicability*

The transponders according to the invention may be made mostly from elements and units available on the market while the non-standard horn-parabolic antennas can be easily produced on the existing plants.

35 The use of the proposed transponders is the most preferable in densely populated areas and especially megalopolises where decrease of environment pollution by biologically active microwave electromagnetic radiation in the UHF and EHF frequencies bands is extremely important.

LIST OF DENOTATIONS USED IN DRAWINGS

- microwave transmitters 1 (additionally denoted as $T_1 \dots T_{4N}$),
output waveguides denoted only with arrows,
transmitting horn-parabolic antennas 2 (additionally denoted as $A_{T1} \dots A_{T4N}$),
5 receiving horn-parabolic antennas 3 (additionally denoted as $A_{R1} \dots A_{R4N}$),
input waveguides denoted only with arrows,
microwave receivers 4 (additionally denoted as $R_1 \dots R_{4N}$),
4N (where $N = 1, 2, 3$, etc.) is number of azimuthal sectors visible in plan view,
at least one router 5,
10 at least one former 6 of direct and return channels,
at least one power supply unit 7;
a monitor 8 of surface air and radio signals propagation in each azimuthal sector,
multichannel adaptive power control unit 9,
return channel's demodulator 10,
15 modulator 11 (connected to the input of the respective microwave transmitter 1),
intermediate support 12
radome 13,
housetop 14,
bit errors analyser 15,
20 unit 16 for decision-making on the output radio signals power adjustment,
interface module 17,
controlled attenuator 18,
rectangular feeding or receiving waveguide 19,
flange 20,
25 horn 21,
divergent walls 22,
flat side walls 23,
parabolic reflector 24;
at least a two-stage trumpet 25,
30 dome-shaped (for example, as a spheroid segment or a pointed cone) roof 26,
alternate protuberant ledges 27 (of a cylinder-like casing),
radio transparent window 28,
smooth gutters 29 (located between said protuberant ledges 27),
deflectors 30 (placed over each said radio transparent window 28),
35 impingement baffles 31.

CLAIMS

1. A terrestrial microwave interactive adaptive transponder comprising:

(1) a transmitting circuit of direct channels of broadcasting and/or interactive data exchange with customers, which is –

5 divided into practically identical azimuthal sectors, and

equipped in each such sector with series of a microwave transmitter, an output waveguide and a transmitting horn-parabolic antenna providing fixed polarisation of radio signal;

10 (2) a receiving circuit of return channels of interactive data exchange with customers, which is –

divided into such practically identical azimuthal sectors those are adjacent apex and in a horizontal projection practically coincide in pairs with the respective azimuthal sectors of the transmitting circuit, and

15 equipped in each such azimuthal sector with series of a receiving horn-parabolic antenna providing fixed polarisation of radio signal, an input waveguide and a microwave receiver,

at that in each pair of said azimuthal sectors of both said circuits

the parabolic reflectors of the transmitting and receiving horn-parabolic antennas have the common vertical symmetry plane, and

20 these antennas are adjusted on mutually orthogonal polarisations of radio signals;

(3) at least one router equipped with a means for connecting to the Ethernet-interface;

(4) at least one former of direct and return channels,

which is connected to the informational outputs of said router and

25 to the informational outputs of which are connected said microwave transmitters and receivers those operate on respective transmitting and receiving horn-parabolic antennas in each said azimuthal sector;

(5) at least one suitable power supply unit and separate circuits of feed and power control of said microwave transmitters and separate feed circuits of said microwave receivers;

30 (6) a monitor of surface air and propagation of radio signals in each of azimuthal sectors of said transmitting and receiving circuits, and

(7) an adaptive power control unit of each of the microwave transmitters, which is connected as a whole to the informational outputs of said monitor and to the control outputs of which the separate circuits of feed and power control of said transmitters are connected.

35 2. The transponder according to claim 1, wherein said receiving horn-parabolic antenna and its microwave receiver are located over respective said transmitting horn-parabolic antenna and its microwave transmitter in each pair of said azimuthal sectors.

3. The transponder according to claim 1, wherein the microwave transmitters and the input waveguides of the all horn-parabolic antennas of the transmitting circuit and the output

waveguides and the microwave receivers of the all horn-parabolic antennas of the receiving circuit are located over the horns respective to them.

4. The transponder according to claim 1, wherein —

each of the transmitting and receiving circuits include $4N$ (where $N = 1, 2, 3$ etc.) said
5 azimuthal sectors with angular value $90^\circ/N$ for the purpose of forming mutually additional
direct and return channels of broadcasting and interactive data exchange with customers,
said former of the direct and return channels is adjusted on the reiteration of working
frequencies in the direct channels through one pair of said azimuthal sector, and
the transmitting and receiving horn-parabolic antennas are adjusted to the same type
10 mutually orthogonal polarisations of radio signals through each two pairs of said azimuthal
sectors.

5. The transponder according to claim 1, wherein said adaptive power control unit in
each said microwave transmitter is supplemented with a gain controller in each said
microwave receiver.

15 6. The transponder according to any claim from 1 to 4, wherein said former of the
direct and return channels has at least one additional input that is meant for connecting to an
analogous TV signals source.

7. A horn-parabolic antenna for said terrestrial microwave interactive adaptive
transponder comprises of electroconductive in whole or at least covered inside by a layer of
20 electroconductive material parts such as:

(1) a rectangular feeding or receiving waveguide equipped with a suitable means for
fastening it to the respective microwave transmitter's or receiver's waveguide,

(2) a horn which is rigidly assembled with said rectangular waveguide and has:
two divergent walls assembled rigidly with two opposite walls of said rectangular
25 waveguide, and

two flat side walls being continuations of two other above-mentioned waveguide's
walls and bounded on one side by identical parabolic arcs;

(3) a parabolic reflector assembled rigidly with said flat side walls of the horn; and

(4) at least a two-stage trumpet being continuation of the horn and having an aperture
30 that exceeds the horn aperture in area extent.

8. The horn-parabolic antenna according to claim 7, wherein said trumpet has two
trapezoidal in profile stages at that the first stage's flare angle exceeds the flare angle of the
second stage.

9. The horn-parabolic antenna according to claim 7 or claim 8, wherein said
35 rectangular feeding waveguide or said receiving waveguide has square cross-section.