the input 3122 and the gate voltages V1 and V3 applied to the respective input 3121 and 3123.

As can be noted from Figure 2, the induction lines ~~3128~~ of gates connected to the capacitances Cgs 3128a of the FETs and the drain induction lines ~~3129~~ connected to the capacitances Cds ~~3129a~~ of the FETs form two low-pass filters.

By suitably designing the dimensions of the two gate and drain lines so as to compensate for the capacitances Cgs 3128a and Cgd ~~3129a~~ it is possible to obtain amplifiers, the cut-off frequency of which exceeds 30 GHz.

Figure 3 shows the functional diagram of a variable attenuator 3130, the function of which is to vary the average frequency attenuation.

The operating principle is that of a conventional pi attenuator. By suitably varying the polarization voltage V4 at the input 3134, for the PIN diodes CR1 and CR2, and the voltage V5 at the input 3135, for the diode PIN CR3, it is possible to vary the three junction resistances thereof and therefore the attenuation of the device.

The direct voltage values on the three diodes must be suitably set taking account also of adaptation of the device on the line with a characteristic impedance of 50 ohm.

Figure 4 shows the functional diagram of an equalizer 3140 which has a slope variable discretely - forming the subject of the co-pending patent application IT-RM2009A000022 referred to here in its entirety - and which has between the input gate 3141 and the output gate 3142 a transfer/attenuation function inversely proportional to the frequency and adjustable by means of the voltages V6 applied to the input 3146 and the voltage V7 applied to the input 3147, which determine the different conduction/inhibiting conditions of the diodes D3, D4, and D1, D2 able to compensate for the effect of loss of insertion of a

• definition of the temperatures T1,T2, ... Ti at which the automatic calibration cycles must be performed.

Once the first prototypes of the circuit to be calibrated have been prepared, the nominal start-of-procedure input voltages (V1i,V2i,V3i,V4i,V5i,V6i,V7i) are determined on the basis of the design calculations and by means of tests on the calibration and alignment bench carried out on the prototypes;

PROCESS STEPS

- 20) initial configuration of the PLC controller with storage of the said start-of-procedure voltages (V1i,V2i, V3i,V4i,V5i,V6i,V7i) in a static memory of the PLC itself;

30) automatic application of the said start-of-procedure voltages (V1i,V2i,V3i,V4i,V5i,V6i,V7i) to the respective input points (3121, 3122, 3123, 31234, 31235, 3146, 3147) of the respective amplifiers 3120, attenuators 3130, and equalizers 3140 of the basic alignment circuits (3100);

31) introduction, into the PLC memory, of the values of the parameters of the calibration cycle which are specific for the circuit to be calibrated and comprising at least:

- the number N_B of ~~sub~~-bands B_i of the circuit to be calibrated; in the example according to Figure 1, $N_B = 4$, there being provided three sub-bands, plus one direct band;
- the temperature values Ti at which the test cycles are performed; in the example illustrated three calibration temperatures T1=25°, T2=-40°, T3=70°C are used;

40) CALIBRATION CYCLE upon variation of the temperature

41) for each pre-defined temperature Ti = T1,T2,T3

42) the temperature of the microwave module is raised to the test temperature T=Ti;

50) Calibration of the variable equalizers 3140 of the alignment circuits 3100 for each band for which the circuit must operate;

51) application of a test signal to the input 1006 of the block 1000 for each ~~sub~~-band Bi of the signals input into the module;

51a) measurement of the slope of the signal in the ~~sub~~-band Bi at the output 4002 of the block 4000.

52) COMPARISON between the slope measured on the output signal 4002 and the characteristic slope of the design specification;

52a) slope measured > slope of the design specification?

YES-> reduction of the slope of the operating ~~sub~~-band Bi by suitably modifying the voltages V6 and V7 at the respective adjustment points (1006, 1007) of the equalizer for the band Bi; and repetition of the comparison

NO->

52b) slope measured < slope of the design specification?

YES-> increase of the slope of the operating ~~sub~~-band Bi by suitably modifying the voltages V6 and V7 at the respective adjustment points (1006,1007,) of the equalizer for the band Bi; and repetition of the comparison

NO->

53) repetition of the cycle for each band Bi of the input signals;

60) CALIBRATION of the amplifiers *4300* and the attenuators 4400 of the common circuits IF 4000;

61) measurement of the average gain (Gtot-m) in the entire operating band between the input 1006 and the output 4002 of the circuit;

62) Comparison with the specification value (Gtot-m-spec) defined during the design stage

62a) Gtot-m > Gtot-m-spec?

YES-> the amplification 4300 is decreased and the attenuation 4400 of the common part IF is increased and the comparison repeated

NO->

62b) Gtot-m < Gtot-m-spec?

YES-> the amplification 4300 is incremented and the attenuation 4400 of the common part IF is reduced and the comparison repeated

NO->

70) CALIBRATION of the amplifiers and the attenuators of the alignment circuits 3100;

71) for each ~~sub~~-band Bi;

72) measurement of the average gain Gm1,Gm2...,Gm_{NB} of the transfer function of the circuit between the input 1006 and the output 4002;

73) calculation of the value Gm-max= max(Gm1,Gm2,...Gm_{NB});

74) calculation of the value Gm-min= min(Gm1,Gm2,...Gm_{NB});

75) comparison between Gm-max and the specification value Gm-max-spec;

75a) Gm-max > Gm-max-spec?

YES-> the amplification *3120* is decreased and the attenuation *3130* is increased in the basic alignment circuit for the band B_i corresponding to Gm-max by adjusting the voltage V1 of the associated amplifiers and the voltages V4,V5 of the associated attenuators;
repetition of the cycle;

NO->

76) Comparison between *Gm-min* and the specification value *Gm-min*-spec

76a) Gm-min < Gm-min-spec?

YES-> the amplification *3120* is increased and the attenuation *3130* is ~~in~~decreased in the basic alignment circuit for the band B_i corresponding to Gm-min by adjusting the voltage V1 of the associated amplifiers and the voltages V4,V5 of the associated attenuators;
repetition of the cycle;

NO->

CLAIMS

1. Process for automatically calibrating a wideband microwave module to pre-defined specification values (Gm-min-spec) comprising at least one alignment circuit (3100) comprising at least one filter (3110), followed by at least one variable amplifier (3120), by a variable attenuator (3130) and by a variable equalizer (3140), the voltage of which can be controlled, being supplied with frequency signals lying within different bands (Bi) and operating at different temperatures (Ti), and for which at the least the following parameters have been defined according to specification:

- temperatures T1,T2, ... Ti at which automatic calibration cycles must be performed
- nominal start-of-procedure voltages (V1i,V2i,V3i,V4i,V5i, V6i,V7i);

characterized in that it comprises the following steps:

20) initial configuration of a PLC controller with storage of the said start-of-procedure voltages (V1i,V2i,V3i,V4i, V5i,V6i,V7i) in a static memory of the PLC controller itself;

30) automatic application of the said start-of-procedure voltages (V1i,V2i,V3i,V4i,V5i,V6i,V7i) to the respective input points (3121, 3122, 3123, 3124, 3125, 3146, 3147) of the respective amplifiers (3120), attenuators (3130), and equalizers (3140) of the basic alignment circuit (3100);

31) introduction, into the PLC memory, pre-defined values of the parameters of the calibration cycle which are specific for the circuit to be calibrated and comprising at least:

- the number N_B of bands (B_i) of the circuit to be calibrated; there being provided three frequency sub-bands, plus one direct band;
- the temperature values Ti at which the test cycles are performed;

40) CALIBRATION CYCLE upon variation of the temperature:

41) for each pre-defined temperature Ti = T1,T2,T3

42) setting the temperature of the microwave module to the test temperature T=Ti;

50) Calibration of the variable equalizers (3140) of the at least one alignment circuit (3100) for each band for which the circuit must operate;

51) application of a test signal to the input (1006) of an input block (1000) connected to the antenna for each frequency sub-band (Bi) of the signals input into the module;

70) Calibration of the amplifiers and the attenuators of the alignment circuit (3100);

71) for each frequency of the sub-bands (Bi);

72) measurement of the average gain ($Gm1,Gm2...,Gm_{NB}$) of the transfer function of the circuit between the input (1006) of the input block (1000) and the output (4002) of a frequency covering block (4000);

73) calculation of the value Gm-max= $max(Gm1,Gm2,...Gm_{NB})$;

74) calculation of the value Gm-min= $min(Gm1,Gm2,...Gm_{NB})$;

75) comparison between Gm-max and the specification value Gm-max-spec;

75a) Gm-max > Gm-max-spec?

YES-> the amplification *3120* is decreased and the attenuation *3130* is increased in the basic alignment circuit for the band B_i corresponding to Gm-max by adjusting the voltage V1 of the associated amplifiers and the voltages V4,V5 of the associated attenuators;
repetition of the cycle;

NO->

76) Comparison between *Gm-min* and the specification value *Gm-min-spec*

74b) Gm-min < Gm-min-spec?

YES-> the amplification *(3120)* is incremented and the attenuation *(3130)* is increased in the basic alignment circuit for the band (B_i) corresponding to Gm-min by

adjusting the voltage (V1) of the associated amplifiers and the voltages (V4,V5) of the associated attenuators;
repetition of the calibration cycle;

NO->

80) Storage of the values of the alignment voltages (V1,V4,V5) corresponding to respective values of the temperature (Ti) in the memory (5000) of the PLC;

90) Repetition of the steps of the process for each temperature (Ti).

140) Start of an automatic test procedure;

150) Generation of a test sheet of the microwave module.

2. Process according to Claim 1, characterized in that said start-of-procedure voltages values are obtained by a preliminary PROTOTYPE CHARACTERIZATION step
involving tests on a calibration bench and alignment performed on prototypes of the module.

3. Process according to Claim 1, characterized in that comprises the steps of compensating the maximum output power and the average value of the gain of an intermediate conversion circuit (4000) within the entire operating band, before the signal is sent to the output (4002) for subsequent processing, said intermediate conversion circuit being part of the wideband microwave module.

4. Process according to Claim 3, characterized in that it comprises a step for definition, according to specification, of the following parameters:

- Gtot-m-spec = Total average gain, according to specification, of the module;
- Gm-max-spec = Maximum gain of the alignment circuit, according to specification, for each band;
- Gm-min-spec = Minimum gain of the alignment circuit, according to specification, for each band;

5. Process according to Claim 4, characterized in that between the step of:

50) Calibration of the variable equalizers 3140 of the alignment circuits 3100 for each band for which the circuit must operate

and the step of

70) Calibration of the amplifiers and the attenuators of the alignment circuits 3100

it comprises the step of

51a) measurement of the slope of the gain of the alignment circuit.

6. Process according to Claim 5, characterized in that between the step of:

50) Calibration of the variable equalizers 3140 of the alignment circuits 3100 for each band for which the circuit must operate

and the step of

70) Calibration of the amplifiers and the attenuators of the alignment circuits 3100

it comprises the step of

51a) measurement of the slope of the amplitude of the signal in the sub-band Bi at the output (4002) of the block (4000).

7. Process according to Claim 5 or 6, characterized in that it comprises the further steps of:

52) COMPARISON between the slope measured on the output signal (4002) of the intermediate conversion circuit (4000) and the characteristic slope of a design specification:

52a) slope measured > slope of the design specification?

YES-> reduction of the slope of the operating sub-band (Bi) by suitably modifying the voltages (V6) and (V7) applied to respective adjustment points (1006, 1007) of the equalizer for the band (Bi); and repetition of the comparison;

NO->

52b) slope measured < slope of the design specification?

YES-> increase of the slope of the operating sub-band (Bi) by suitably modifying the voltages (V6) and (V7) at the respective adjustment points (1006,1007) of the equalizer for the band (Bi); and repetition of the comparison

NO->

53) repetition of the cycle for each band (Bi) of the input signals;

60) Calibration of the amplifiers (*4300)* and the attenuators (*4400)* of the common intermediate frequency conversion circuits (4000);

61) measurement of the average gain (Gtot-m) in the entire operating band between the input (1006) and the output (4002) of the circuit;

62) Comparison with the pre-defined specification value (Gtot-m-spec)

62a) Gtot-m > Gtot-m-spec?

YES-> the amplification (4300) is decreased and the attenuation (4400) of the intermediate frequency conversion (4000) is increased and the comparison repeated;

NO->

62b) Gtot-m < Gtot-m-spec?

YES-> the amplification (4300) is increased and the attenuation (4400) of the intermediate frequency conversion (4000) is decreased and the comparison repeated

NO->

8. Process according to Claim 3, characterized in that it comprises the further steps of

100) Measurement of the Noise Figure (NF) for each of the operating sub-bands (Bi);

110) Comparison between the measured value (NFm) and a pre-defined value (NFspec) of the specification;

110a) NFm not to the pre-defined value of specification?

YES->increase in the gain of the input preamplifier 2012;
repetition of the entire calibration cycle for all the temperatures Ti;

NO->

120) Measurement of the linearity of the transfer function between the input (1006) and the output (4200) for each of the sub-bands (Bi);

130) Comparison between the linearity measured and the pre-defined values of specifications

130a) Linearity not to the pre-defined values of specification?

YES-> increase in the attenuation of the input stage (2013);
repetition of the entire calibration cycle for all the temperatures (Ti)

NO->

140) Start of the automatic test procedure.

CLAIMS

1. Process for automatically calibrating, according to pre-defined specification values of a plurality of calibration parameters (Gm-min-spec; Gm-max-spec; Ti; Vi; Bi), a wideband microwave module comprising at least one basic alignment circuit each comprising at least one filter, followed by at least one variable amplifier, by a variable attenuator and by a variable equalizer, the voltage input/s of which can be controlled, being supplied with frequency signals lying within different bands (Bi) and operating at different temperatures (Ti), and for which at least the following calibration parameters have been defined according to specification values:

- temperatures T1,T2, ... Ti at which test cycles of the automatic calibration cycle must be performed;
- nominal start-of-procedure input voltages (V1i,V2i,V3i,V4i,V5i, V6i,V7i);
- Gm-max-spec = Maximum gain of the alignment circuit/s, according to specification, for each band;
- Gm-min-spec = Minimum gain of the alignment circuit/s, according to specification, for each band;

there being provided an intermediate frequency conversion block, which performs conversion to the intermediate frequency of the signal incoming from the alignment circuit/s and which has an output;

characterized in that it comprises the following steps:

20) initial configuration of a PLC controller with storage of the said start-of-procedure input voltages (V1i,V2i,V3i,V4i, V5i,V6i,V7i) in a static memory of the PLC controller itself;

30) automatic application of the said start-of-procedure input voltages (V1i,V2i,V3i,V4i,V5i,V6i,V7i) to the respective input points of the respective amplifier/s, attenuator/s, and equalizer/s of the basic alignment circuit/s ;

31) introduction, into the PLC memory, of pre-defined values of calibration parameters of the calibration cycle which are specific for

each microwave module to be calibrated and comprise at least:

- the number N_B of bands (B_i) of the microwave module to be calibrated; there being provided three frequency sub-bands, plus one direct band;
- the temperature values Ti at which the test cycles of the calibration cycle are to be performed;

40) CALIBRATION CYCLE upon variation of the temperature:

41) for each pre-defined temperature Ti = T1,T2,T3

42) setting the temperature of the microwave module to the test temperature T=Ti;

50) Calibration of the variable equalizers of the at least one basic alignment circuit for each band for which the microwave module must operate;

51) application of a test signal to the input of an input block connected to an antenna for each frequency band (Bi) of the signals input into the module;

51a) measurement of the slope of the gain of the alignment circuit or of the slope of the amplitude of the signal in the band Bi at the output of the intermediate frequency conversion block,

52) COMPARISON between the slope measured and a characteristic slope of a design specification:

52a) slope measured > slope of the design specification?

YES-> reduction of the slope of the operating band (Bi) by suitably modifying the voltages (V6) and (V7) applied to respective adjustment points of the equalizer for the band (Bi); and repetition of the comparison cycle (51a, 52, 52a;52b) ;

NO->

52b) slope measured < slope of the design specification?

YES-> increase of the slope of the operating band (Bi) by suitably modifying the voltages (V6) and (V7) at the respective adjustment points of the equalizer for the band (Bi); and repetition of the comparison cycle (51a, 52, 52a;52b);

NO->

53) repetition of the cycle (51-52) for each band (Bi) of the input signals;

70) Calibration of the amplifier/s and the attenuator/s of the basic alignment circuit/s;

71) for each frequency of the bands (Bi);

72) measurement of the average gain ($Gm1, Gm2..., Gm_{NB}$) of the transfer function of the microwave module between the input of the input block and the output of the frequency conversion block;

73) calculation of the value $Gm\text{-}max = max(Gm1, Gm2, ...Gm_{NB})$;

74) calculation of the value $Gm\text{-}min = min(Gm1, Gm2, ...Gm_{NB})$;

75) comparison between Gm-max and the specification value Gm-max-spec;

75a) Gm-max > Gm-max-spec?

YES-> the amplification is decreased and the attenuation is increased in the basic alignment circuit for the band B_i corresponding to Gm-max by adjusting the input voltage (V1) of the associated amplifier/s and the input voltage/s (V4,V5) of the associated attenuator/s;
repetition of the cycle (72,73,74,75+75a);

NO->

76) Comparison between Gm-min and the specification value Gm-min-spec

76a) Gm-min < Gm-min-spec?

YES-> the amplification is incremented and the attenuation is decreased in the basic alignment circuit for the band (B_i) corresponding to Gm-min by adjusting the input voltage (V1) of the associated amplifier/s and the input voltage/s (V4,V5) of the associated attenuator/s;
repetition of the cycle (72,73,74,75,76,76a);

NO->

80) Storage of the values of the said adjusted input voltages (V1,V4,V5) corresponding to respective values of the temperature (Ti)

in the memory of the PLC;

90) Repetition of the entire cycle for each temperature (Ti).

140) Start of an automatic test procedure;

150) Generation of a test sheet of the microwave module.

2. Process according to Claim 1, characterized in that said start-of-procedure voltages values are obtained by a preliminary PROTOTYPE CHARACTERIZATION step involving tests on a calibration bench and alignment performed on prototypes of the module.

3. Process according to Claim 1, characterized in that it comprises the steps of compensating the maximum output power and the average value of the gain of the intermediate frequency conversion block within the entire operating band, before the signal is sent to the output for subsequent processing, said intermediate frequency conversion block being part of the wideband microwave module.

4. Process according to Claim 3, characterized in that it comprises a step for definition, according to specification, of the following parameters:

- Gtot-m-spec = Total average gain, according to specification, of the module.

5. Process according to Claim 4, characterized in that it comprises the further steps of:

60) Calibration of the amplifiers and the attenuators of the common intermediate frequency conversion block;

61) measurement of the average gain Gtot-m in the entire operating band between the input and the output of the module;

62) Comparison with the pre-defined specification value Gtot-m-spec

62a) Gtot-m > Gtot-m-spec?

YES-> the amplification is decreased and the attenuation of the intermediate frequency conversion block is increased and the comparison repeated;

NO->

62b) Gtot-m < Gtot-m-spec?

YES-> the amplification is increased and the attenuation of the intermediate frequency conversion is decreased and the comparison repeated

NO->

6. Process according to Claim 3, characterized in that it comprises the further steps of

100) Measurement of the Noise Figure (NF) for each of the operating bands (Bi);

110) Comparison between the measured Noise Figure value NFm and a pre-defined Noise Figure value NFspec of the specification;

110a) NFm not to the pre-defined value of specification?

YES->increase in the gain of the input preamplifier;

repetition of the entire calibration cycle for all the temperatures Ti;

NO->

120) Measurement of the linearity of the transfer function between the input and the output for each of the bands (Bi);

130) Comparison between the linearity measured and the pre-defined values of specifications

130a) Linearity not to the pre-defined values of specification?

YES-> increase in the attenuation of the input stage;

repetition of the entire calibration cycle for all the temperatures (Ti)

NO->

140) Start of the automatic test procedure.