

A coupler

FIELD

The present invention relates to a coupler.

BACKGROUND

A connector or coupler is used for electrically connecting two devices so as to pass a signal. A connector may include a female metal contact on one side, which engages with a male metal contact on the other side. However, such connectors may suffer from the following problems:

1. The connection performance may degrade due to oxidation and wear after time.
2. When the data rate is ultra high ($>10\text{Gb/s}$) the area of each contact becomes very small.
3. The small mechanical parts are very easily damaged.
4. The fabrication is expensive.

An alternative to metal connectors is a wireless signal connection. However, a wireless connection is less ideal due to electromagnetic interference (EMI) and limited frequency resource. A further promising alternative is a dielectric connector, for example US patent number 7481672. However, such prior art dielectric connectors are mainly useful for DC isolation and still suffer from EMI problems, especially in the unconnected state. EMI problems can relate to the device being overly susceptible to interference from other devices, and/or that the device causes excessive interference in other devices.

SUMMARY



159159



G00002

In general terms the present invention proposes a resonant electromagnetic (EM) coupler which does not radiate significantly in an unconnected state. This may have the advantages(s) that:

1. no metal contacts are required,
2. EMI may be substantially eliminated for both connected and disconnected status,
3. consistent performance over the device lifetime,
4. longer life-time,
5. water resistant,
6. wideband . >10GHz bandwidth @centre frequency 60GHz (or relative bandwidth>16%) and hence much higher data rate (>10Gb/s) can be achieved,
7. no radio frequency license needed,
8. safer data transmission because there is no radiation leakage to environment, any information transmission is point-point. Thus the connection security is higher than common wireless communications where the transmission can be detected by many others besides of the desired receiver, and/or
9. better looking compared with metal cable connector and can be invisible.

In a first specific aspect there is provided an electromagnetic coupler comprising:

- a transmitter configured to operate at a first central frequency,
- a first termination configured to connect to the transmitter and having a second resonant frequency,
- a receiver configured to operate at the first frequency,
- a second termination configured to connect to the receiver and having a third resonant frequency,

wherein when the first and second terminations are brought into close proximity when engaged, the equivalent resonant frequency is substantially the first frequency, and wherein the second and/or third frequencies being substantially spectrally spaced from the first frequency.

BRIEF DESCRIPTION OF DRAWINGS

One or more example embodiments of the invention will now be described, with reference to the following figures, in which:

Figure 1 is the schematic of a dielectric connector according to a first embodiment,

Figure 2 is an equivalent circuit diagram and graph of frequency response of the dielectric connector,

Figure 3 is a perspective view of a second embodiment,

Figure 4 is a frequency response graph of the second embodiment,

Figure 5 is a cross section of an inserting type connector according to a third embodiment,

Figure 6 is a cross section of a touching type connector according to a forth embodiment, and

Figure 7 is a cross section of a two way connector according to a fifth embodiment.

DETAILED DESCRIPTION

A dielectric coupler 100 is illustrated in Figure 1 according to the first embodiment. A data stream to be transmitted may firstly up/down converted to a millimetre wave (MMW) frequency by modulator 102. The signal from the modulator 102 passes to a transmitter (Tx) side termination 104, which is engaged with a receiver (Rx) side termination 106, whereby the signal will be transmitted via RF from one to the

other. The signal passes from the Rx termination to a demodulator 108 for down/up conversion.

When the two terminations 104,106 are disconnected, the signal will be reflected back instead of radiated into the atmosphere. When two terminations 104,106 are connected, the couplers have just dielectric touching and the signal is transferred without any significant leakage. So whether the coupler is connected or not, there is no external RF signal radiation and the leakage may be insignificant.

The coupler is based on a resonant frequency shifting principle, which is illustrated in Figure 2. When the connector is “disconnected”, the Tx termination 104 resonant frequency 200 is higher than the working frequency 202 of the MMW modulator and oscillator 102, as a result, the Tx termination 104 impedance is significantly mismatched and hence the RF power transferred externally. However, when the connector is “connected”, a high dielectric constant material sheet is sandwiched between Tx and Rx terminations 104,106. This high dielectric constant material will increase the equivalent capacitance of the resonance structure of the terminations 104,106. Hence the resonance frequency 204 is reduced. By carefully designing the structure size in terms of the material dielectric constant, the connected state will have a resonant frequency equal to the working central frequency of the Tx and Rx. Thus, the coupler will pass the signal when the terminations are engaged. If the gap between Tx and Rx is very small, almost all signal power is transmitted from Tx to Rx, except for the material loss. The radiation leakage is small.

Figure 3 shows a dielectric coupler according to the second embodiment. It includes a Tx termination 300 and a Rx termination 302. The Tx termination 300 is shown in Figure 3(b). It includes a substrate 304 and antenna 306 without a high dielectric

constant material plane. The Rx termination 302 has almost the same structure as the Tx termination 300 except a high dielectric constant plane 308 is attached.

The Tx termination 300 is made on PCB material (e.g. FR408). In Figure 3, the Tx termination 300 includes metal parts exposed (top layer). However, the Tx termination 300 can be covered by another non-metal film (e.g. Teflon). The dielectric constant of this non-metal film should be very different as compared with the high dielectric constant material on the Rx termination 302. The backing substrate is FR408. Other low dielectric constant PCB substrate materials can also be used. For 60GHz working frequency, the design dimensions may be: loop diameter 1mm, slot width 0.075mm, patch inside dipole 0.38mm x 0.15mm, dipole width 0.6mm. The coupler is fed by micro-strip line to the centre of the metal patch from back of the PCB.

The coupler performance according to the second embodiment is shown in Figure 4. The central frequency is 58GHz. In the connected state (Figure 4 (a)), the propagation (S_{21}) is high at the central frequency and -3dB bandwidth is >15GHz. The impedance matching frequency bandwidth ($S_{11} < -10\text{dB}$) is 10GHz. The wide impedance bandwidth is contributed by the slot loop plus slot dipole structure shown in Figure 3 (b). By carefully designing the centre frequencies for the slot loop and slot dipole, the bandwidth may be maximised.

The slot loop and slot dipole may be used to enlarge the bandwidth by locating 2 resonant frequencies close to each other so that the corresponding pass-bands are partial overlaid. This will result in a wider bandwidth. Two resonant frequencies are controlled by the slot loop and slot dipole, respectively. For example, by increasing the slot loop diameter, one of the resonant frequencies is reduced, while by shortening the length of the slot dipole, the other resonant frequency is increased.

The propagation loss is 1.38dB at the central frequency in the connected state. That means more than 70% of the energy may be transferred from Tx to Rx. The reminder is mainly material losses, and a small part is radiation leakage. In the disconnected state (Figure 4 (b)), the return loss is small (0.7dB). Thus most of the energy (85%) is reflected back to the Tx instead of radiated to air.

A coupler may be modified by designing the bandwidth (eg: 10GHz), dielectric constant material (eg: ~11) and radiation leakage rate according to the requirements of a given application.

To further reduce any RF leakage, an absorber may surround the terminations. The absorber should have small effect to coupler parameters. Thus less dielectric constant absorber foam or rubber is preferred. The absorbing rate should be as high as possible.

The dielectric connector can be modified according to the requirements of a given application. Three examples are introduced below.

Figure 5 shows an inserting type coupler 500. In Figure 5(b) the Tx termination 502 includes an surround structure 504 with a slot opening 506 and the surround structure 504 is absorber. In the disconnected state, the small radiation leakage from the Tx element 510 is absorbed by the absorber 504. In Figure 5(a) the Rx termination 512 includes a high dielectric constant material 514. In the connected state, shown in Figure 5(c), the Rx termination 512 is inserted in the slot opening 506, then the signal is transmitted from Tx to Rx through high dielectric material 514. The small radiation leakage in connected state is also further absorbed by the absorber 508.

Figure 6 shows a touching type coupler 600. The Tx 602 and Rx 604 terminations face each other. To maximise the terminations alignment, some self-alignment structure is needed. . For example with a central working frequency of 60GHz, dielectric constant of 10.2, then the mechanical tolerance is about $\pm 0.1\text{mm}$ to ensure good coupling. There are many kinds of self-alignment systems that can be used, such as magnetic; embossing. An absorber 606 placed under the Tx termination to further reduce the radiation leakage in the connected and disconnected states.

In the previous embodiments, the Rx resonant frequency may be fixed at the working frequency because the high dielectric constant material is permanently provided on the Rx side. To achieve 2-way communications, an individual reverse connector could be provided as shown in Figure 7. By using the same principle of resonance frequency shifting, frequency shifting for both sides of the connector can be achieved. Namely the Tx can be at right side and/or left side of the following connector structure for 2-way communications in single dielectric connector. Here the high dielectric constant material neither touches the right coupler nor left coupler until connected, and thus leakage from either side is prevented in the unconnected state.

While example embodiments of the invention have been described in detail, many variations are possible within the scope of the invention as claimed as will be clear to a skilled reader.

CLAIMS

1. An electromagnetic coupler comprising
a transmitter configured to operate at a first central frequency,
a first termination configured to connect to the transmitter and having a second resonant frequency,
a receiver configured to operate at the first frequency,
a second termination configured to connect to the receiver and having a third resonant frequency,
wherein when the first and second terminations are brought into close proximity when engaged, the equivalent resonant frequency is substantially the first frequency, and wherein the second and/or third frequencies being substantially spectrally spaced from the first frequency.
2. The coupler in claim 1 further comprising a dielectric material between the first termination and the second termination.
3. The coupler in any preceding claim further comprising an RF absorber adjacent to or surrounding the first termination and/or the second termination.
4. The coupler in any preceding claim wherein the bandwidth of the coupler is greater than 16%.
5. The coupler in any preceding claim wherein the RF leakage is less than 15%.
6. The coupler in claim 2 wherein the dielectric material is provided on the second termination and the third frequency is substantially similar to the first frequency.

7. The coupler in claim 2 wherein the dielectric material is configured to be spaced from the first termination and the second termination when unengaged and sandwiched between the first termination and the second termination when engaged, wherein the second and third frequencies being substantially spectrally spaced from the first frequency.
8. The coupler in any preceding claim wherein the first termination is configured to insert into the second termination.
9. The coupler in any preceding claim wherein the first termination and the second termination are configured to touch when in close proximity.
10. The coupler in claim 9 further comprising a self alignment structure.
11. The coupler in any preceding claim wherein the first frequency is MMW.
12. The coupler in any preceding claim wherein the first termination and/or the second termination comprise a slot loop and/or slot dipole arrangement.
13. The coupler in claim 12 wherein the slot loop and slot dipole arrangement have closely spaced and partially overlapping band pass characteristics.
14. The coupler in any preceding claim wherein the second frequency is greater than two times the first frequency.
15. A coupler termination according to any preceding claim.