EFFICIENT DISTRIBUTED ANTENNA DESIGN USING TAPPERS AND DIRECTIONAL COUPLERS

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Introduction

This paper is designed to help RF Engineers involve in the design of Distributed Antenna Systems (DAS) to understand the effect of using tappers and/or directional couplers in their design.

In this paper, we will discuss tappers and directional couplers, including how they work. We will also present the impact of using one versus the other in the system design.

Tapper

Signal power tappers, signal taps, power tappers, or just taps are passive RF devices designed to draw a small portion of power from the main transmission line without causing substantial insertion loss. Power tappers also can be defined as an uneven signal divider. The incoming power is unevenly divided between the two output ports. A tapper is typically a 3-port device but may come with many additional tap port configurations. They are based on capacitive coupling, not direct coupling. The taps ports should be set to the impedance of the main transmission line. They must be properly terminated to ensure optimal performance.

In an electronic schematic, the tapper usually is illustrated using a symbol like the one shown in figure 1 below.

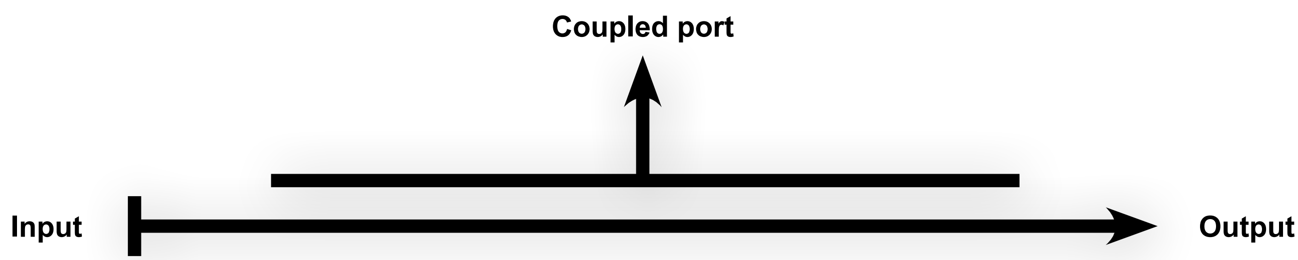


Figure 1

Tappers are usually constructed using coaxial tubes of different diameters. The outer tube is coaxially aligned with the center conductor. The center conductor is designed to conduct the main portion of the power applied to the input port. The distance between the outer tube and center conductor and the diameter of the outer tube and the center conductor's diameter will determine the coupling ratio between ports and the output port impedances. In the picture below (Figure 2), you will see the tapper's construction we described above.

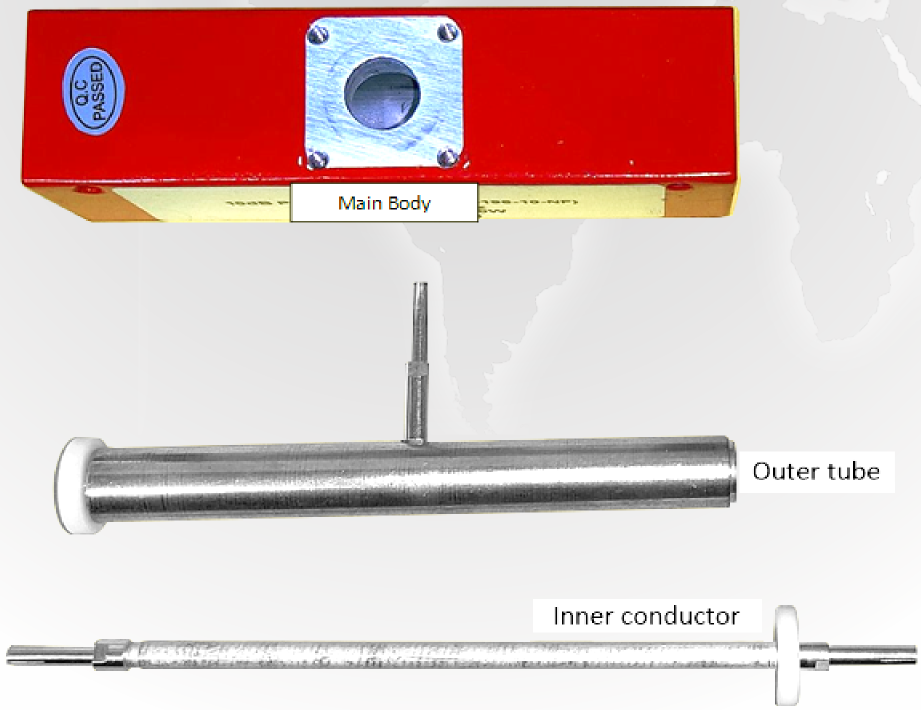


Figure 2

A tapper normally has coupling values that range from 3 to 35dB.

Directional Coupler

Directional Couplers are passive RF devices designed to draw a small portion of power from the main transmission line without causing substantial loss. Directional Couplers can be defined as an uneven signal or power divider. This is because the incoming power is divided unevenly between 2 output ports. The directional coupler is generally constructed as a 3-port device, as shown in figure 3.

Figure 3

In an electronic schematic, A directional coupler is illustrated with a symbol like the one shown in Figure 4.

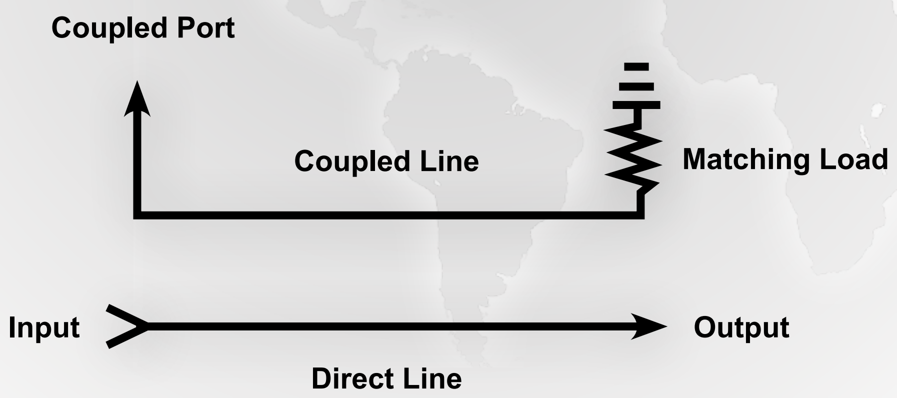


Figure 4

Directional couplers are usually designed and manufactured utilizing a printed circuit board. The distance between the direct line and coupled line, as well as the thickness of the lines and their lengths, will determine the coupling ratio as well as the frequency and bandwidth of the coupler. You will notice an Impedance Matching load on the end of one of the coupling sides. Coupling values are usually manufactured between 3 to 35dB.

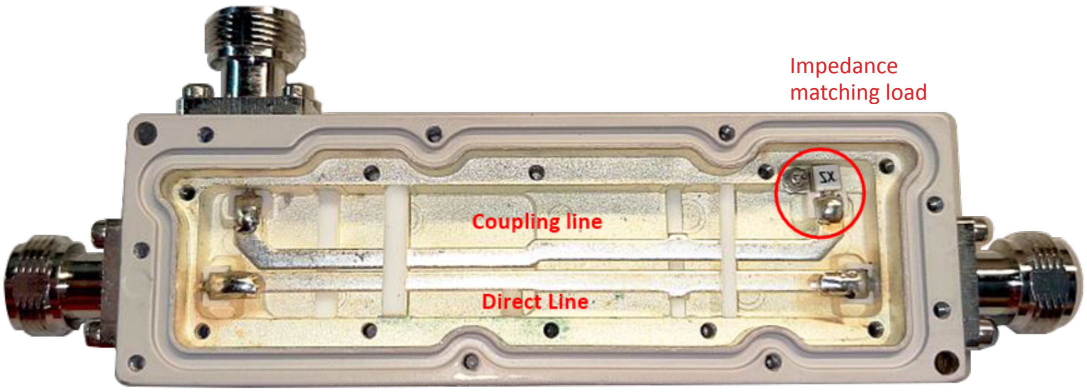


Figure 5

Occasionally directional couplers have two coupled ports. Usually, they have one coupled output, as shown in figure 5. The second output port has an internal Impedance matching load with no output connector.

Coupler's energy efficiency may be increased by using both coupled ports, as shown in the example in figure 6 below. In this example, a 20dB directional coupler has two coupled ports connected to antennas that radiate RF energy toward target coverage areas. In this example, the 15dB coupler has one port (As shown in figure 5). In this case, the RF energy, which is directed to the second port, is converted into heat in an internal matching load.

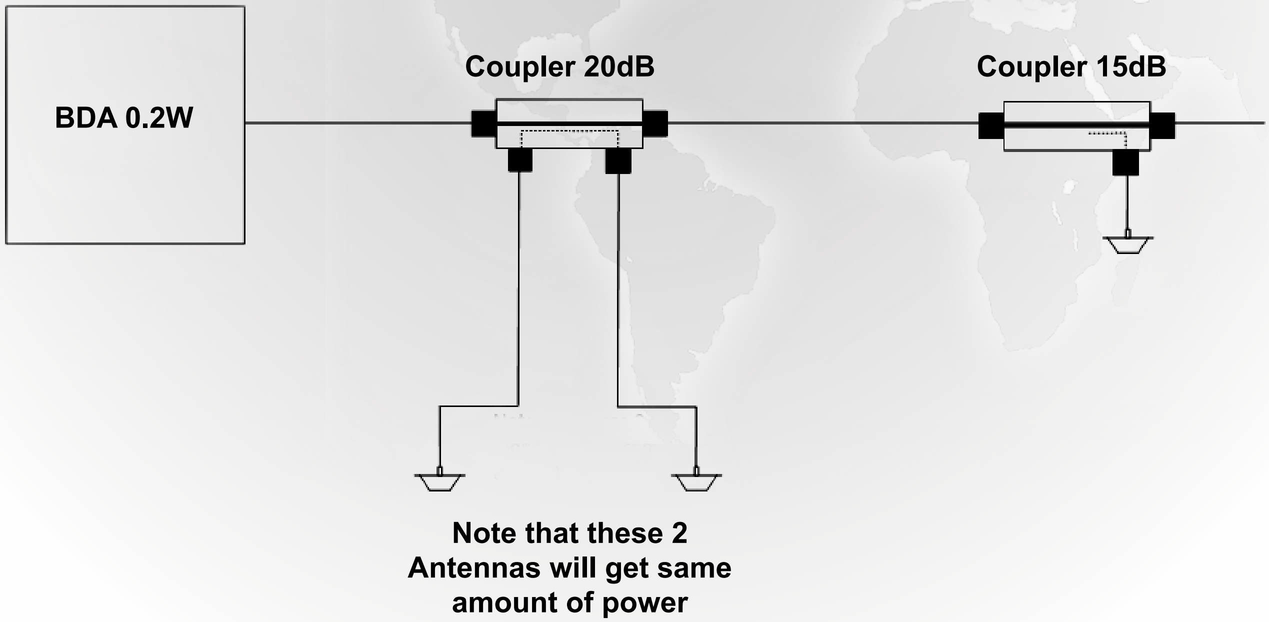


Figure 6

How is DAS design impacted by using a tapper instead of a directional coupler?

The main purpose of a tapper or a directional coupler in a DAS design is to provide balanced power distribution from the RF sources toward serving antennas by unevenly dividing energy from RF Sources. It will simplify link budget calculations providing the same coverage area for each antenna supplied by approximately the same RF Power. Of course, we must consider additional obstacles in our designs like elevator shafts, stairs, walls, etc. 'Let's examine a simple example of link budget calculations for two feeding lines in the DAS system.

Our example will be a passive DAS system on 1900MHz using tappers. In this example, we will calculate the downlink and uplink link budget for antennas 3 and 7. Then we will compare calculated values to the same design replacing the tappers with directional couplers keeping the same coupling values.

Downlink link budget is calculated as:

Power at antenna = Power from RF Source (26dBm) – cable losses – Tapper/Coupler losses + antenna gain (0dBi)

The uplink link budget is calculated as :

Power at input connector of RF Source = Power received at antenna (-50dBm) + antenna Gain (0dBi) – Cable loss – Tapper/Coupler losses

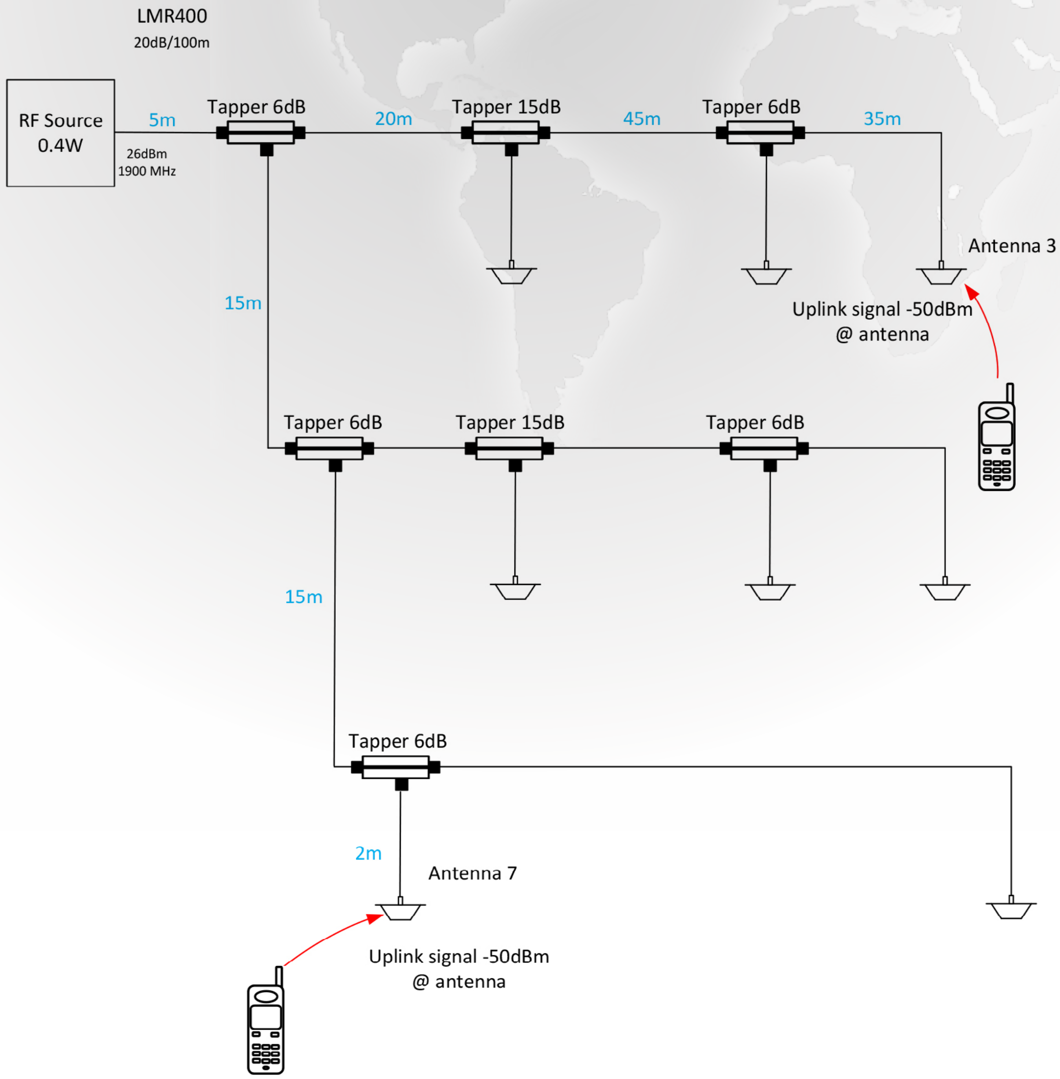


Figure 7

Antenna 3

Downlink with	Tappers	Couplers
	Attenuating Value	
105m of LMR 400 Cable	21 dB	21 dB
Insertion Loss	2.64 dB	3.65 dB
Downlink Signal (at Antenna 3)	**2.36 dBm**	**1.35 dBm**

Uplink with	Tappers	Couplers
	Attenuating Value	
105m of LMR 400 Cable	21 dB	21 dB
Insertion Loss	2.64 dB	3.65 dB
Uplink Signal (at RF Source)	**-73.64 dBm**	**-74.65 dBm**

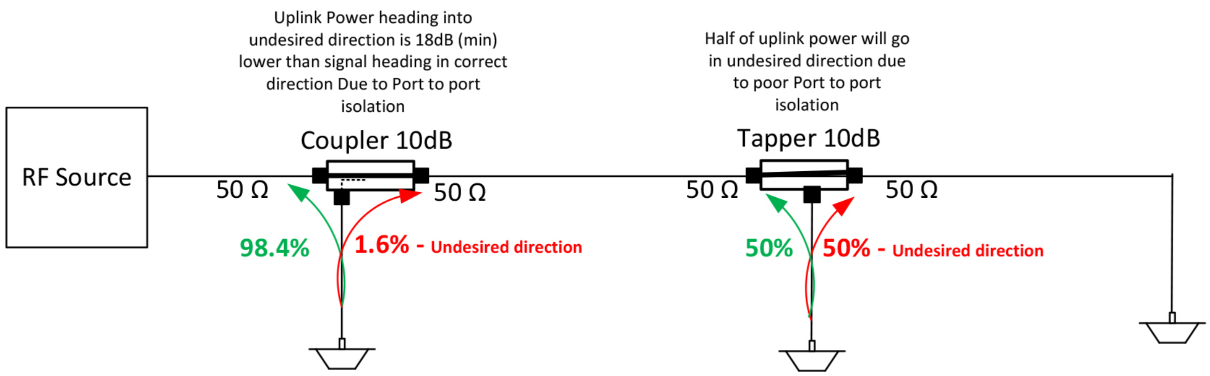
With respect to antenna 3 you will notice there is no substantial difference between couplers and tappers in the antenna 3 line. In this case, the insertion losses of tappers and couplers are similar.

Antenna 7

Downlink with	Tappers	Couplers
	Attenuating Value	
37m of LMR 400 Cable	7.4 dB	7.4 dB
Tapper loss	18 dB (3x6dB)	18dB (3x6dB)
Downlink Signal (at Antenna #3)	**0.6 dBm**	**0.6 dBm**

Uplink with	Tappers	Couplers
Attenuating source	Attenuating Value	
37m of LMR 400 Cable	7.4 dB	7.4 dB
Tapper loss	27 dB	18 dB
Uplink Signal (at RF Source)	**-84.4 dBm**	**-75.4 dBm**

By looking at antenna 7, you shall notice that the uplink signal's value at the RF Source is significantly different. If you chose to use tappers, the uplink signal would be 9dB lower than that example using Directional couplers. This is due to the low isolation values between the uplink and output ports of the tapper. In this case, the directional couplers are your best choice. As the graphical interpretation of uplink power flow, please refer to Figure 8.



Converting uplink circuitry into electrical schematic (Using Ohm's and Joule's laws) , we have following schematic representing situation above

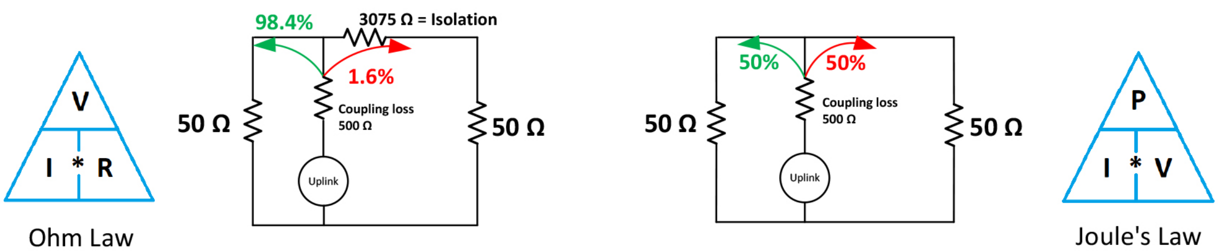
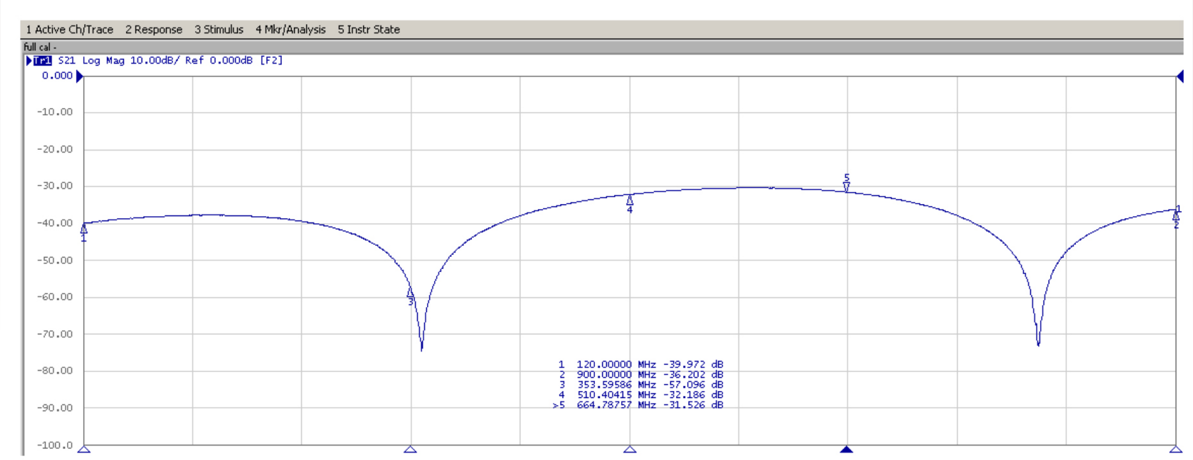


Figure 8

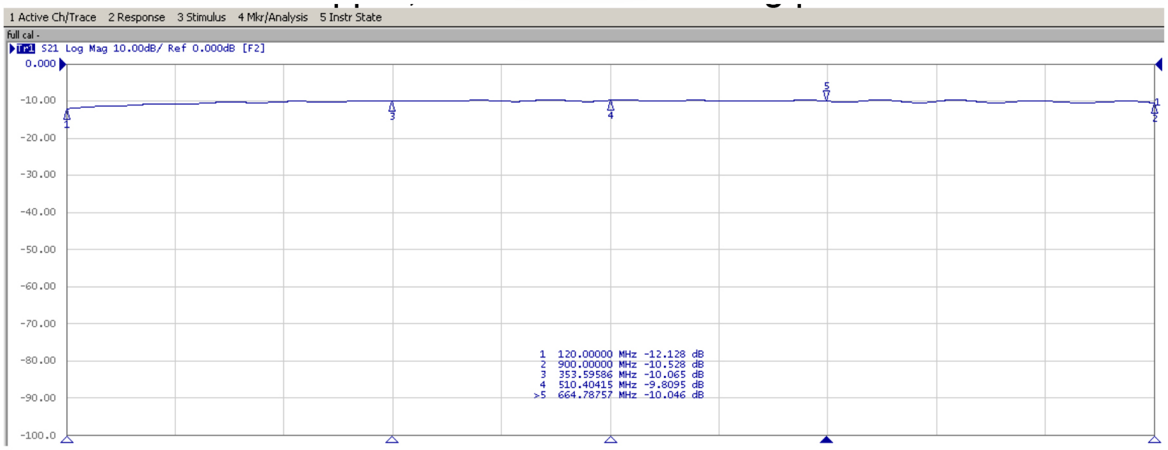
In the case of a tapper, in the uplink path, there is coupling loss plus an additional 3dB loss made by dividing the uplink signal equally between input and output ports. Each of the ports is terminated by 50 Ohm cables, couplers, tappers, antennas, and other equipment, making the uplink signal evenly split between ports.

In the directional coupler case, the isolation between ports is a minimum of 18dB, which significantly decreases the uplink insertion loss.

Altogether, the uplink link budget is different for different branches of your DAS, which may negatively impact your overall DAS performance. The curves below represent measured directivity values. The graph below shows the directivity (Isolation + Coupling Value) measured between the coupled and output ports on the directional coupler. This is showing the entire spectrum from 120MHz to 900MHz. In this example, we are using a 10dB Coupler, the isolation is calculated as (I=Directivity-coupling value) 30-10=20dB



In the case of the tapper, we have the following plot:



Here, the directivity is 0dB (10-10dB), so the tapped port signal is divided evenly between the input and the output port. Unlike the directional coupler, this causes a 3dB insertion loss introduced by the tapper itself on top of the coupling value of 10dB.

Conclusion

A. Advantage of Couplers

If your uplink signal path loss is impacting your uplink system design (noise figure, signal to noise ratio, etc.) and/or you find that your mobile terminal must transmit using a higher power setting to make up for the higher uplink path loss, then consider deployment of directional couplers to equalize your uplink and downlink path loss and save your customer mobile device battery life.

In a DAS design for a public safety system, it is highly recommended to use the directional couplers rather than the tappers to minimize the chance of a lost or dropped call in the uplink direction.

B. Advantage of tappers

The most significant advantage of the tapper is the simplicity of construction. Just considering its size, there is a substantial difference in manufacturing cost between the two devices. As a result, production costs are low, which provides low prices as compared to directional couplers. By comparison, directional couplers range between 2-3 times the tapper price.

In the case of one-way communication as broadcast radio, paging, including mobile terminals which 'don't have any uplink power regulation, the uplink path loss 'isn't a concern, tappers may be used.

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