5.8GHz Cantenna Radar

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Abstract- The goal of the project is to build a low cost Doppler radar with coaxial microwave parts and to develop circular waveguide Cantenna construction. In this project 5.8GHz continuous wave (CW) signal is transmitted. The radar system is constructed by using hardware components such as Cantenna, voltage controlled oscillator, power amplifiers, splitter, mixer, and video amplifier. The entire system is powered using a 24V battery. The acquired data from the radar system is recorded by using audacity software and save as ".wav" file. This ".wav" file is processed in Matlab. The measurements are taken on the road inside the MAEU campus. The result of velocity can be viewed with personal computer (PC).

Index Terms- 5.8GHz, Cantenna, Doppler, Matlab, Radar

I. INTRODUCTION

Radar is used in many fields. In aerospace, it is used as an aircraft detection system. Similarly, on the sea it is used to detect the speed and distance of ships. Currently, this technology has been employed in other areas, like the detection and movement of weather formations, motor vehicles and terrain. In addition, the costs and complexities of radar depend upon the number of functions and its application areas. Radar has a variety of applications such as surveillance, remote sensing, imaging and measurement of altitude. Each application uses various principles of radar operation [1].

This project involves the design, fabrication and testing of laptop-based radar system that is able to operate continuous wave for velocity measurement. The radar frequency at 5.8 GHz is expected to produce accurate results due to the decrease in wavelength of electromagnetic radiation.

The radar system is expected to operate in C band with approximately +15 dBm of transmitted power. Two Cantennas are used in transmitter and receiver, respectively. The Matlab code is used for data acquisition and signal processing. The experimental data is shown Doppler versus time intensity (DTI). We collect test measurement data by using audacity [2].

II. SYSTEM BLOCK DIAGRAM

Overall block diagram of small radar system is shown in Fig.1. In CW operation, the radar system consists of voltage control oscillator (VCO), amplifiers, splitter, antennas, mixer and video amplifiers. In transmitting, the VCO operates at a constant voltage (Vtune) as the input to generate a signal at 5.8 GHz. This signal is fed through amplifier and then splitter. The splitter separates the incoming signal into two output ports. One output goes directly to the transmitter antenna, and the other goes to the
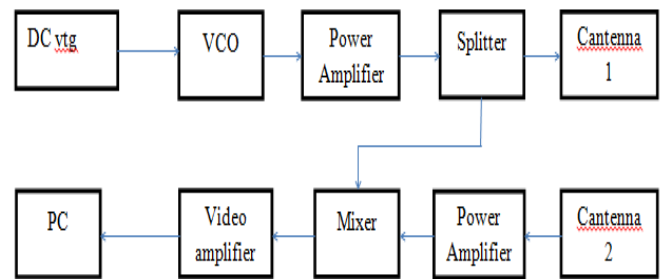
local oscillator (LO) port of the mixer in receiver. In receiving, the received signal is fed through an amplifier and to the radio frequency (RF) port of the mixer. The intermediate frequency (IF) signal of the mixer has a constant voltage for a fixed target. The output signal on the IF port is fed to a video amplifier circuit. Finally, the output signal is connected to a PC's audio-in port to record ".wav" file. We use Matlab software to determine the Doppler shift from the recorded data.

Figure 1: Overall Block Diagram

III. HARDWARE DESIGN

A. Cantenna

To save cost, Cantenna is chosen for the transmitter and receiver of the radar system. Cantenna is directional antenna and radiate greater power in one direction. Fig.2 shows dimensions of Cantenna.
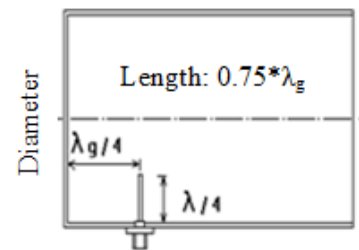

Figure 2: Functional Dimensions of Cantenna

The following equations are used for Cantenna design.
Wavelength of transmit signal:

$$\lambda = \frac{c}{f} \qquad (1)$$

where c is 3×10^8 ms^{-1} and f is transmitted frequency.

$$\text{Length of monopole} = \frac{\lambda}{4} \qquad (2)$$

Minimum radius of Can:

$$r_{min} = \frac{ck}{2\pi f} \qquad (3)$$

where k is Eigen value of circular waveguide for TE_{11} mode and f is lower cut-off frequency.

Maximum radius of Can:

$$r_{max} = \frac{ck}{2\pi f} \qquad (4)$$

where k is Eigen value of circular waveguide for TM_{01} mode and f is upper cut-off frequency.

$$\text{Position of monopole} = \frac{\lambda_g}{4} \qquad (5)$$

For circular waveguide,

$$(\frac{1}{\lambda})^2 = (\frac{1}{\lambda c})^2 + (\frac{1}{\lambda g})^2 \qquad (6)$$

where λ_g is standing wavelength inside the tube and λ_c is wavelength for maximum Can diameter.

By using maximum radius of Can:

$$\lambda_c = \frac{2\pi r}{k} \qquad (7)$$

where k is Eigen value of circular waveguide for TE_{11} mode

$$\text{Length of Can} = 0.75 \times \lambda_g \qquad (8)$$

So, the dimension of the Can is 65mm length and 40mm in diameter. The connector used for the Cantenna is the SMA connector SMA864L model. The most suitable Cantenna spacing is four inches apart. Fig.3 shows finished Cantenna design.
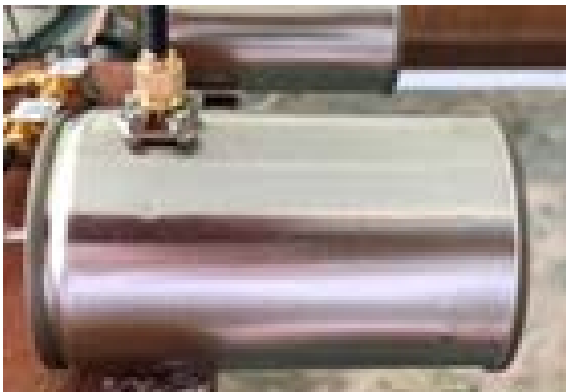

Figure 3: Finished Cantenna Design

B. Voltage Controlled Oscillator (VCO)

As shown in Fig.4, ZX-95-5776+ VCO generate about 5.8GHz signal with +1.6dBm at tuning voltage of 3.2 Vdc [3].
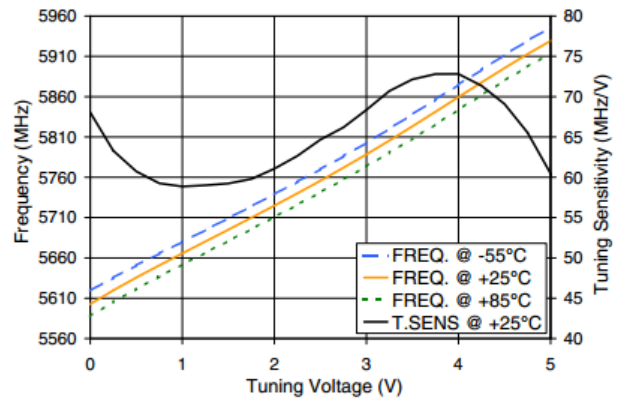

Figure 4: Typical Performance Curve of ZX-95-5776+

C. Power Amplifiers (transmitter)

In transmitter, power amplifiers are used to increase the power level of signal at the output. To reduce power dissipation of amplifier, we cascade the two amplifiers in the design. At 5.8GHz, ZX60-V63+ amplifier provide about 14dB gain [4] and ZX60-V81-S+ provides 6.5dB gain as shown in Fig.5 and Fig.6. So, the total output power gain of VCO and the two power amplifiers is 19.1 dBm including 1dB compression loss for each component.
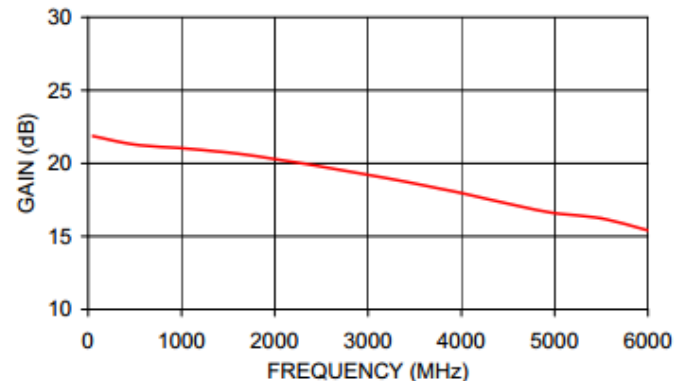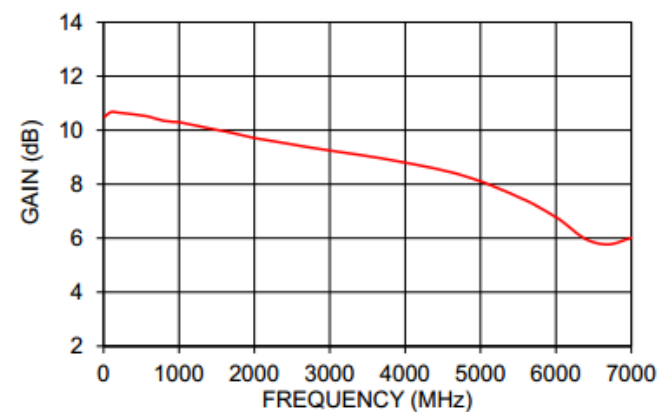

Figure 5: Typical Performance Curve of ZX60-V63+

Figure 6: Typical Performance Curve of ZX60-V81

D. Splitter

ZX10-2-71-S+ power splitter is used to separate the incoming signal into two at port 1 and 2. Since port 1 and port 2 losses are 3.1 dB and 3.2 dB, splitter output port 1 to transmitter is 16 dBm

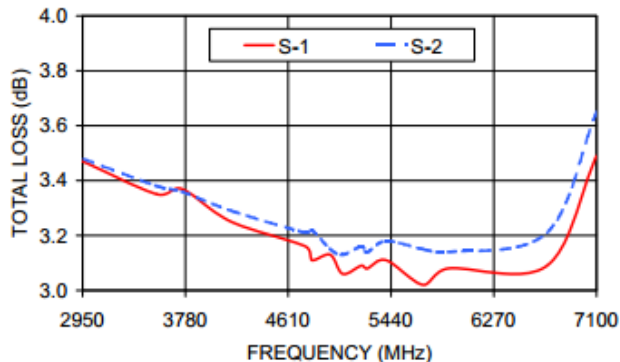and 15.9 dBm at port 2 to the mixer.Fig.7 shows the losses of ZX10-2-71-S+ for port 1 and port 2[5].

Figure 7: Port 1 and Port 2 Losses of ZX10-2-71-S+

E. Low Noise Amplifier (LNA)

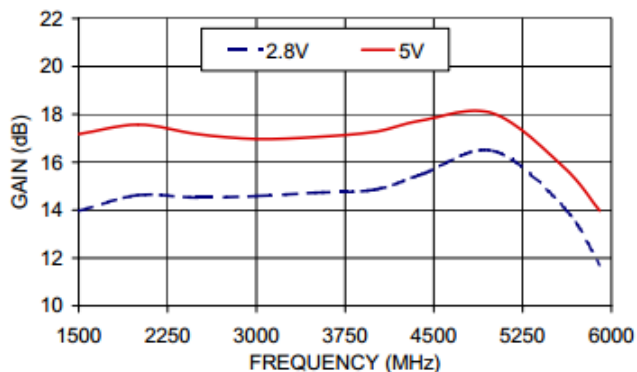ZX60-5916M-S+ LNA is able to provide 14.5dB at 5.8 GHz as shown in Fig.8 [6].

Figure 8: Typical Performance Curve of ZX60-5916M-S+

F. Mixer

ZX05-C60S+ mixer in our design detect the phase difference between LO and RF port. Its level is 16 for LO power +15dBm [7].
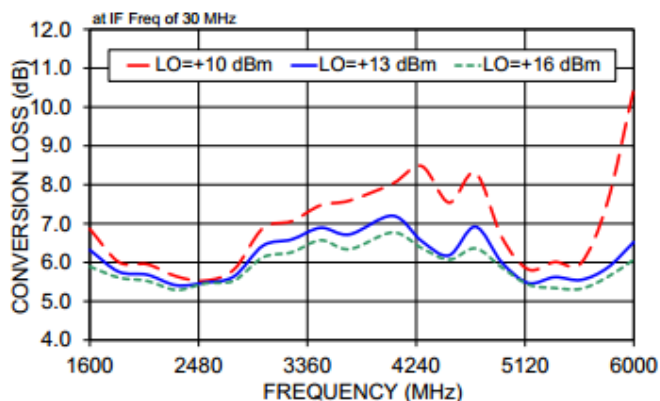

Figure 9: Typical Performance Curve of ZX05-C60S+

G. Video Amplifier

It will be designed into two stages such as gain stage and filter stage. At first the gain stage is designed. After the gain stage, the signal is fed through a 15 KHz Sallen-Key low pass filter circuit to avoid aliasing to the PC's audio input port. Fig.10 shows MAX414 video amplifier schematic.

In gain stage, the gain value can be calculated by the equation:

$$G = 1 + \frac{R_f}{R_i} \qquad (9)$$

In this project, R_f will be 10kΩ variable resistor and R_i will also be 220Ω. The gain result of this project is 7.82. To get this value, 10kΩ variable resistor is adjusted up to 1.5kΩ.

In filter stage, it can be designed to be 15 kHz frequency because this frequency value is in audio input ranges. Thus, fourth order low pass filter is designed.

To calculate 15kHz, we choose R1=R2=R6=R7=R=10kΩ and C2=C3=C4=C5=C=1nF. In this circuit, the following equation is used:

$$f = \frac{1}{2\pi RC} \qquad (10)$$

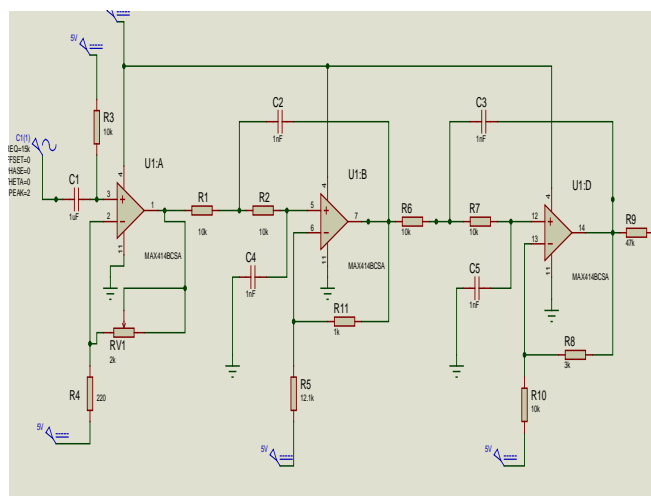Then the value of calculated frequency is 15.9 kHz.

Figure 10: MAX414 Video Amplifier Circuit

IV. SIGNAL PROCESSING:MATLAB CODE ANALYSIS

Recorded ".wav" file is processed and analyzed in Matlab software code. Fig.11 shows program flow chart for Doppler.
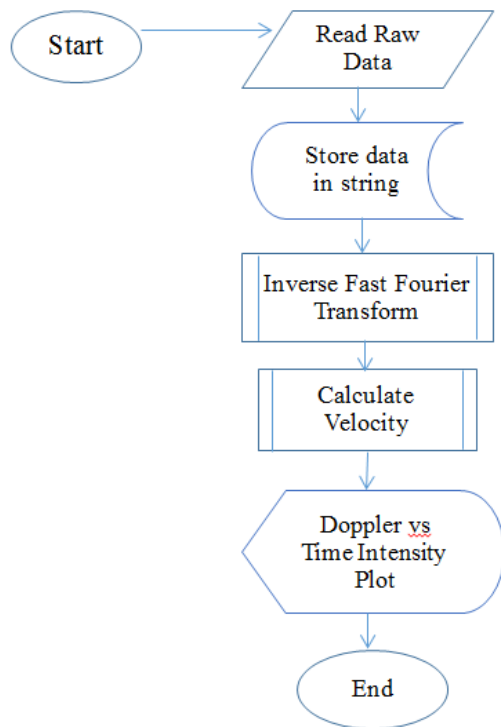
Figure 11: Program Flow Chart for Doppler

V. TEST AND RESULTS

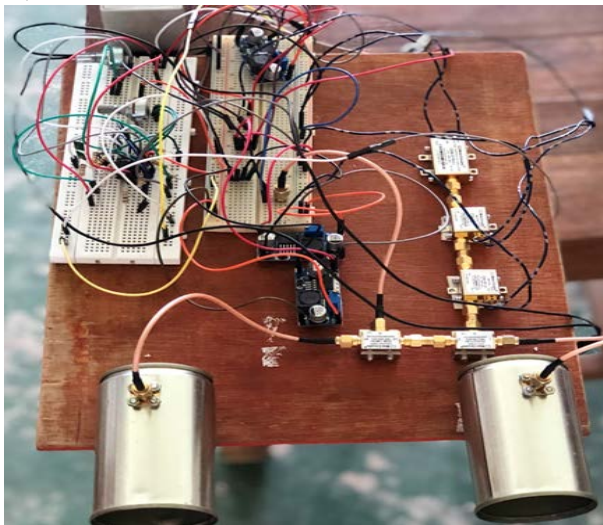The final assembled of 5.8 GHz Cantenna radar is shown in Fig.12.

Figure 12: 5.8GHz Cantenna Radar

A. Video Amplifier Test

As the mixer output is about 40mV, so the function generator is set 15 kHz and 40mV to the input of video amplifier. The output signal on the oscilloscope is 1Vpp. Fig.13 shows MAX414 gain stage with low-pass filter.
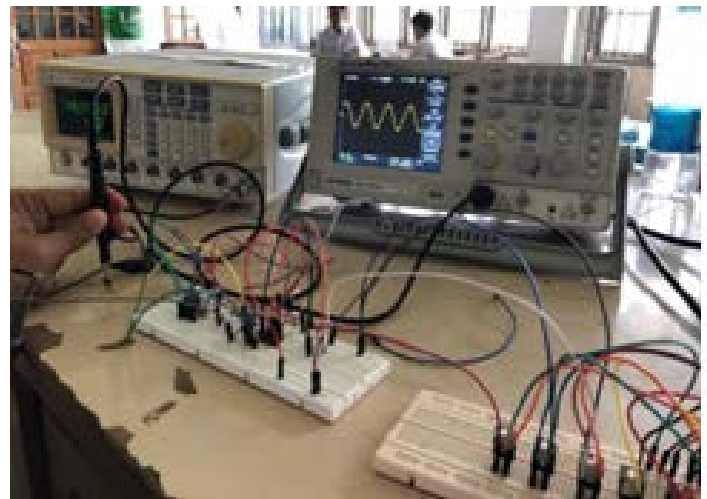

Figure 13: MAX414 Gain Stage with Low-Pass Filter

B. Doppler Test (Indoor)

To test the system performance, we connect the V-tune pin of voltage control oscillator to the DC voltage source. Then connect audio cable to PC and record data. The audio recording software for this project is Audacity with sampling rate of 44.1 kHz for every ".wav" file. Power on the system and move a metal in front of the system at different time and speed to record the Doppler Effect. The recorded ".wav" is as shown in Fig.14.

In Fig.14, we can see the first signal at about 20s. Next signal is recorded from 35s to 45s. The speed of the two signals is different as shown in Fig.15.
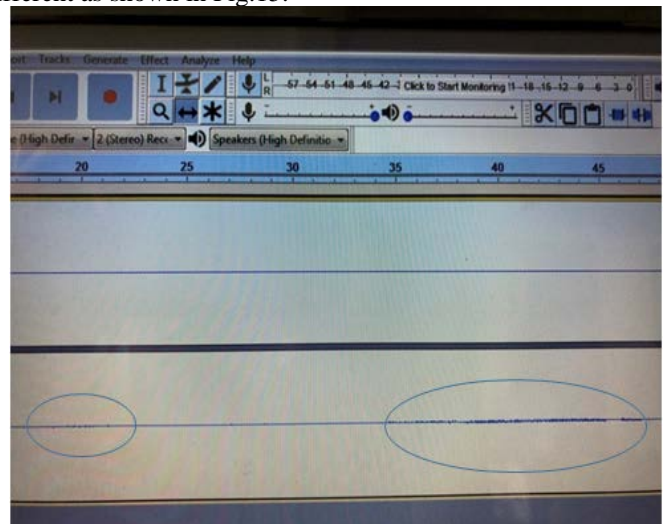

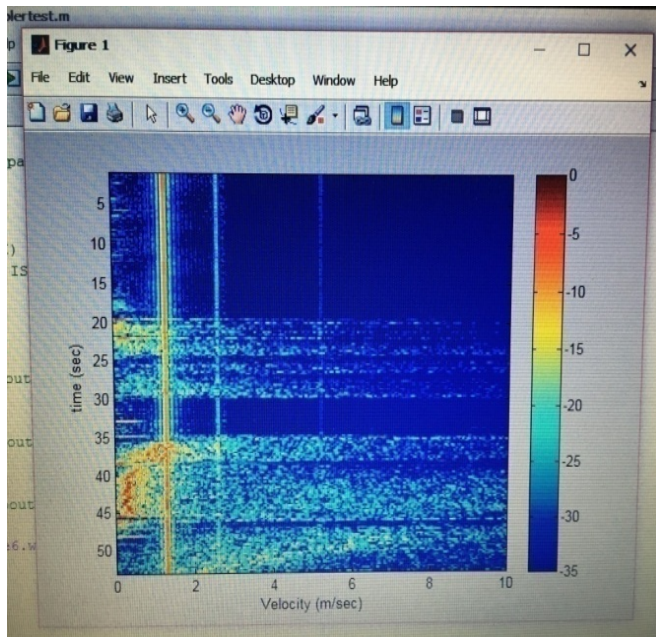Figure 14: Recorded Audio File with Moving Metal in Audacity

Figure 15: DTI Output Plot for moving metal in Matlab

C. Outdoor Test

For this test, a moving vehicle will be in the experiment to measure the Doppler Effect. Data is recorded when vehicle pass through the radar. The height of the radar system is placed 18 inches above the ground at an angle of 45 degrees. We use PC to record the Doppler test ".wav" file and use Matlab code to produce a DTI plot. Fig.16 shows a motorcycle passing through the road with the speed which is about 36kmh[-1]. At about 9.5s, the vehicle passed through the radar and the changing of color provides the strength of signal.
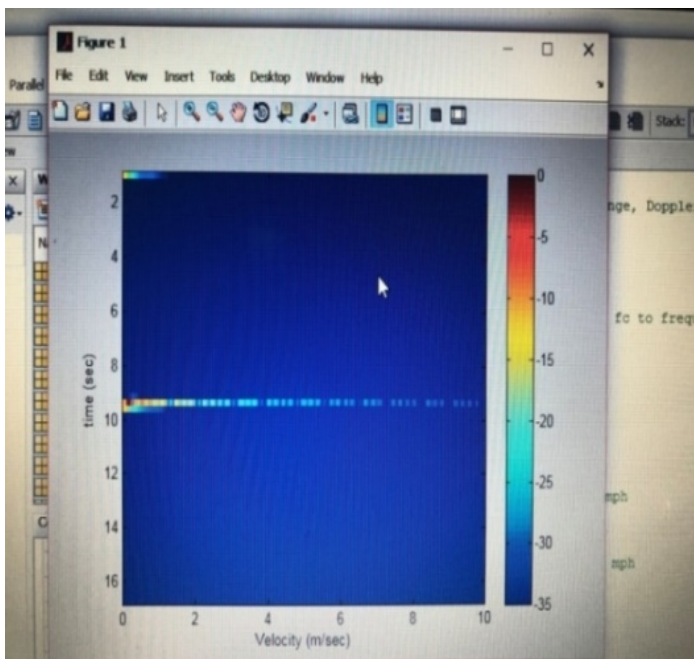

Figure 16: DTI Plot of Vehicle Driving at 10ms^{-1}

VI. CONCLUSION

This project covered the entire engineering process involved in designing and implementing a radar system. Using a high resolution Analog-to-Digital converter with microcontroller could increase the speed of data processing and accuracy of measurement. For low cost advantage, Doppler radar is widely used in all over the world for short distance sensing. This project can be used to minimize the number of accidents over the road.

ACKNOWLEDGMENT

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[2] Kevin Chi-Ming Teng, *The design and evaluation of a 5.8 GHz laptop-based radar system*, 2013.
[3] https://www.minicircuits.com/pdfs/ZX-95-5776+
[4] https://www.minicircuits.com/pdfs/ZX60-V63+
[5] https://www.minicircuits.com/pdfs/ZX10-2-71S+
[6] https://www.minicircuits.com/pdfs/ZX60-5916M-S+
[7] https://www.minicircuits.com/WebStore

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