DESIGN OF

RECTANGULAR PATCH ANTENNA ARRAY

FOR 5G WIRELESS COMMUNICATION

Semester-V

Antennas and Wave Propagation

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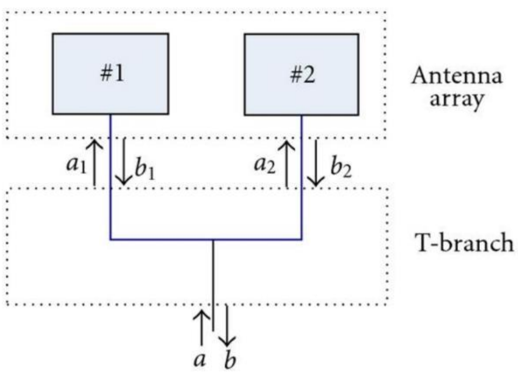
Objective:

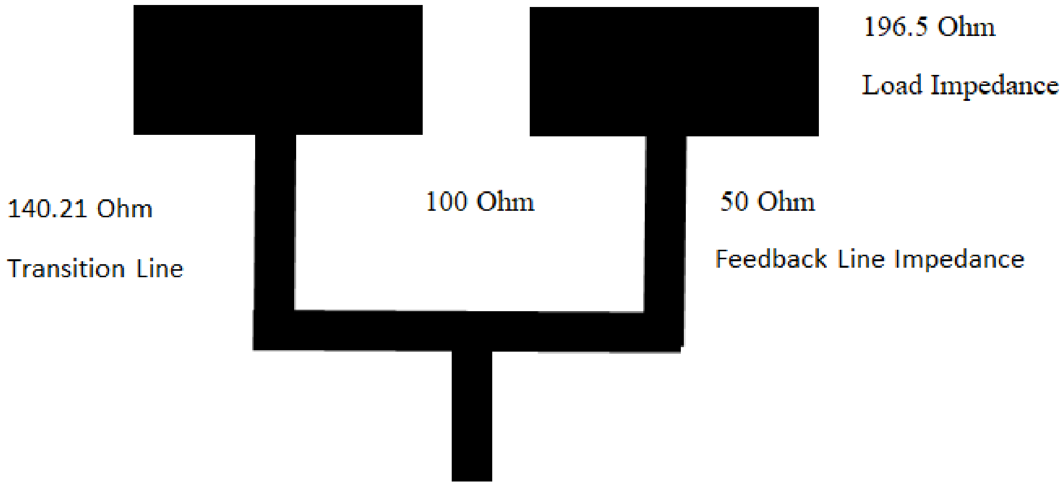
We have planned to design a two-element array antenna for 5G wireless communication using CST Microwave Studio. Our design contains two rectangular patches on a Roger RT-5880 LZ, dielectric constant ε_r =2.2 and loss tangent δ=0.0025. The rectangular patch is chosen because it is convenient to design and analyse. The rectangular patch also has large impedance bandwidth due to it's broader shape compared to other types.

Design:

Our proposed design consists of two rectangular patches (1 and 2) called as antenna array with a T-junction power divider. The T-junction power divider is a simple 3-port network and can be implemented in any kind of transmission medium such as a Microstrip, strip line, coplanar waveguide, etc. A 3-port network cannot be lossless, reciprocal, and matched at all the ports. Therefore, since a T-junction power divider is lossless and reciprocal, it cannot be perfectly matched at all of the ports.



Schematic of Two patch antenna



Our Proposed Design of Two element array antenna (without Fractal Geometry)

Two patch antenna array is used to improve the gain and impedance bandwidth. The 50 Ohm feedline is matched with 100 Ohm Microstrip Line. We are using this type to improve antenna's directivity and bandwidth.

Frequency:

We think this antenna operating Frequency will be 25GHz to 34GHz (Theoretically). We need to check these values on simulation. We would be expecting the gain around 10 decibels and return loss would be less than 10 decibels. We chose this range because it is one of the potential bands for 5G since wide bandwidth of 1GHz will be available. The 28 GHz mm Wave spectrum – with an overall band range from 27.5 to 29.5 GHz – is used exclusively by satellite players but is also considered a super-efficient band for 5G services. 5G mm Wave not only unlocks extreme capacity and multi-Gigabit throughput that fuel cost-efficient unlimited data plans in dense networks today, but it also enables us to realize the full potential of 5G.

Substrate Material:

The dielectric material we plan on using for the substrate of our patch antenna is the Roger RT-5880, a glass-microfiber reinforced PTFE composite. This composite has a dielectric constant of 2.20, which is near the lower bound of the dielectric constant required for substrate of patch antennas (2< ε_r<12). Lower values of dielectric constant allow for higher resonant frequency and larger antenna dimensions, leading to larger bandwidth, essential for 5G applications. The Roger RT-5880 also has a high efficiency of around 80%, compared to other substrates like Bakelite/FR4 and RO4003. The Microstrip patch is made by photoetching copper onto the substrate. The length of the patch is between λ/3 and λ/2, where λ is the resonant wavelength of the antenna. By choosing the frequency of transmission to be 28GHz, the mode of transmission to be TM (010) and the patch antenna to be rectangular shaped with Roger RT-5880 substrate, the formula for the length of the Microstrip patch is related to frequency by:

$$f_{r(010)} = \frac{v_0}{2L\sqrt{\epsilon_r}}$$

where v_0 is the speed of light through free space, L=length of patch and ε_r = dielectric constant of the substrate.

Dimensions:

We will be choosing a substrate of thickness = 0.762 mm. The width of the patch is given by the formula:

$$W = \frac{\lambda_0}{\sqrt{2\ \epsilon_r + 2}}$$

Substituting our operating frequency = 28GHz, we get W = 4.24 mm.

A similar formula exists for calculating the effective length of the Microstrip patch due to the fringing effect, where ε_{reff} is given by:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + 12\frac{h}{W}}}$$

Substituting $\varepsilon_r = 2.20$ and W = 4.24 mm, h=0.762 mm, we get $\varepsilon_{reff} = 1.938$

The effective length of the patch is given by:

$$L_{eff} = \frac{\lambda_0}{2\sqrt{\varepsilon_{reff}}}$$

Also, $L_{eff} = L + 2\nabla L$

where, $\nabla L = \frac{0.412d(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}$

Hence, $L_{eff} = 3.848\,mm$ and L = 3.154 mm. For the microstrip patch, the impedance is given by

$$Z_L = 90(\frac{\varepsilon_r^2}{\varepsilon_r-1})(\frac{L}{W})$$

Hence, the load impedance of the Microstrip patch = 200Ω

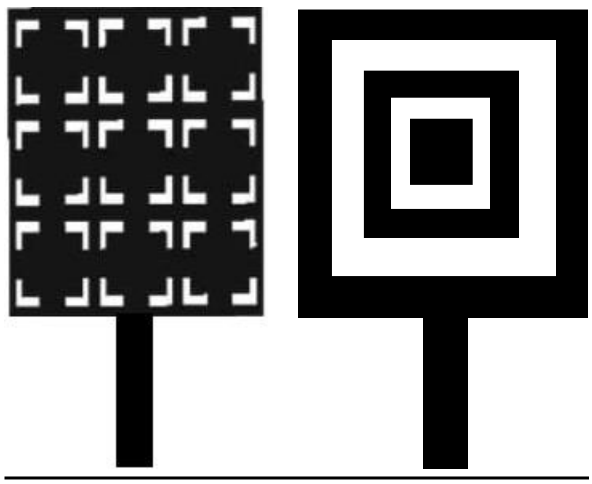
Since the impedance of the coaxial line is 50Ω, a quarter-wave transformer is used to match the line to the patch antenna. The impedance of the line must be 100Ω.

Substitute this value to find the width of the transition line, we get w = 0.366 mm. Similarly, the width of the 50Ω line is calculated to be 2.738 mm

Application:

- We have planned to use Roger RT-5880 which is a flexible material. Hence our antenna can be used in wearable devices.
- We can also implement point to point digital radio antennas because radio system uses antenna array to allow bi-directional data flow.
- The antenna can be used in Commercial airline telephones.
- Due to isotropic property, uniformity of Roger material it is used for satellite application.

Novelty:



- We have planned to implement the above fractal designs for each of the two array element.
- The fractal design provides good multiband performance, wide bandwidth and small area.
- The rectangular shape improves bandwidth and feed radiation because it has a broader shape.
- The two element array increases directivity of the antenna.
- Due to low dielectric constant, we can achieve higher bandwidth and as a result high data rate can be achieved.